Fixation and Stimulus Control of Behavior

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FIXATION AND STIMULUS CONTROL OF BEHAVIOR

by

DAVID S. STARK

A Thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of Master of Science

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The purpose of this thesis is to present systematically some fundamental principles concerning stimulus control of behavior and then to consider behavioral fixation within the framework of these principles. The discussion of behavioral fixation is not only concerned with original experimentation on the subject but is intended also to serve as a thorough review of the literature on behavioral fixation. The empirical basis for this thesis is experimental investigations as opposed to correlational investigations or narrative descriptions of behavior. The general principles presented herein are discussed in relation to a variety of specific experiments.

This thesis is primarily oriented toward behaviorism, which I believe to be the most basic approach to understanding behavior—the most basic in the sense that other worthwhile approaches, from the purely physiological to the cybernetic, should ultimately relate to behavior as viewed from a behavioristic standpoint. The behavioristic orientation of this thesis is strict in that mentalistic or cognitive interpretations of behavior are accorded no consideration. The principles and experimental results with which this thesis is concerned are discussed in terms of cause and effect as opposed to teleology.

The thesis is divided into two main parts, each of which has two subdivisions, A and B. Part I is concerned with general prin-
ciples of stimulus control of behavior. Part IA, the first subdivi-

dvision of Part I, presents a broad operational framework for the

subject, and a number of operational terms are defined in Part

IA. The material in Part IA is intended primarily as helpful back-
ground for the more substantively important material in Part IB,

where the material from Part IA is documented and extended with

many illustrations from the literature. Most of these illustra-
tions are from experiments having murids as subjects, but the gen-

eral principles involved are so fundamental that they cannot be

considered peculiar to any taxon. To an extent the material in

Part IB is developed in logically vertical fashion in that materi-

al presented at any one point may be prerequisite for an under-

standing of more profound topics discussed later.

Part II presents an in-depth discussion of research dealing

with behavioral fixation. Part IIA begins with a definition of

fixation and later goes on to review and to interpret the litera-
ture on fixation. This literature is concerned almost entirely

with fixation in rats. Part IIB presents original research on fix-

ation in mice.

Although original research is discussed only in Part IIB, the

remainder of the thesis is largely original with regard to the way

in which the literature findings are interpreted and integrated

with each other. In fact, though the overall conceptual picture

portrayed in Part I would seem basic to any concrete understanding

of behaviorism from a cause-effect viewpoint, to my knowledge such

a holistic picture has never before been outlined adequately in
the behavioral literature. In Part IIA the interpretations applied to the fixation literature are entirely original and mark the first time that any integrated interpretative approach has been able to deal precisely with the great variety of findings concerning fixation. In addition, the discussion in Part IIA represents the only comprehensive and up-to-date review of the literature on fixation. In order to keep the scope of this thesis within manageable limits, the literature cited has been selected to exclude references concerning behavior of nonmammals and of humans in experiments that involve verbal variables or verbal instructions on how to respond. In addition, whereas Part II is intended to serve as a comprehensive review of the relevant subject matter, the literature cited in Part I is highly selective to include only those references that have an essential bearing on the fundamental issues.

A number of terms are defined in the thesis, especially in Part IA, primarily because most of these terms are linguistically essential in discussing the subject matter of this thesis. A secondary purpose of defining these terms is because they are mnemonically useful vehicles for pigeonholing concepts and because use of these terms may help the reader to associate the subject matter in this thesis with material in the behavioral literature. To this end, the definitions provided herein are intended to correspond with usage of the defined terms in the behavioral literature insofar as such correspondence would accord with the overriding purpose of presenting the definitions: to contribute to the logical
development of the empirical subject matter under consideration. It is granted that usage of some terms varies in the behavioral literature, but the definitions stated in this thesis are, in my opinion, reasonably consistent with common behavioristic usage except as indicated otherwise in the text.

The text contains numerous cross-references. These are intended only as references, analogous to literature references, and are not signals that the reader must turn to another part of the text. The textual material at any given point is reasonably self-contained provided that the reader has become sufficiently acquainted with the pertinent foregoing material.

In Part I a single underlying principle unifying all others is that behavioral change occurring within the individual is a Darwinian process. In the text every cardinal aspect of such processes is precisely specified and related to behavior. In Part II a focal point for discussion is the proposal, amply supported, that fixation is a correlate of the Darwinian nature of behavioral change.

I wish to express my appreciation to Dr. Charles L. Scudder for his helpful criticisms throughout all stages of preparation of this thesis. I am also indebted to Drs. Yvo T. Oester and Robert D. Wurster, the other two members of my thesis committee, for their time and their interest in this thesis. I am particularly grateful to my parents for their unfailing help and encouragement.

David S. Stark
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Part I

STIMULUS CONTROL OF BEHAVIOR

A. OPERATIONAL CONCEPTS AND DEFINITIONS
Chapter 1

ENVIRONMENT AND BEHAVIOR

IA-1.1. Stimuli and Responses

This thesis is concerned with basic principles pertaining to "stimulus-response relationships," i.e., to stimulus effects on behavioral responses. According to common usage the words stimulus and response refer respectively to any environmental or behavioral phenomenon. Interpretation of this definition hinges on how the phrase "environmental or behavioral phenomenon" is interpreted. Therefore, since any discussion of stimuli and responses requires first and foremost a clear understanding of what the words "stimulus" and "response" mean, it is appropriate to begin by considering what constitutes an environmental or behavioral phenomenon.

Although one might think that the terms "environment" and "behavior" designate mutually exclusive classes of phenomena and events, simplistic distinctions between environment and behavior cannot be made without running into dilemmas. For example, a lever press by a rat might be considered an environmental event on the simplistic grounds that the lever movement occurs externally to the rat. Yet a behavioral scientist recording such a lever movement could legitimately maintain that he was recording a behavioral as opposed to an environmental event.

In some cases environment cannot be unambiguously distinguished from behavior at all without resorting to arbitrary and banal criteria. In other cases, however, a useful distinction can
be made. In order to clarify the distinction, it will be helpful to give formal definitions of the terms "activity," "environment," and "behavior."

IA-1.2. Activity, Environment, and Behavior

Except as noted below, an animal's activity is defined as the phenomena and events for which the animal's secretions or muscular contractions are necessary. The term "activity" thus subsumes such phenomena and events as locomotion, salivation, eating, grooming, vocalization, the movement of a lever that the animal presses, changes in the electrical conductivity of the skin, etc. From a behavioristic standpoint an animal's environment is defined as the phenomena and events that can affect the animal's activity and which in turn can be directly affected by some explicit source other than the animal's activity.

In behavioral experimentation this "explicit source" is the investigator's activity, specifically his conduct of experiments. In the above definition of "environment," the crucial word "directly" is meant to indicate a direct effect in the sense that any treatment variable by definition is directly affected by the investigator's activity. Any treatment variable affecting an experimental animal's activity is thus environmental by the definition of "environment." On the other hand, any dependent variable as such is affected indirectly, if at all, by the investigator's activity and thus cannot be considered environmental by the definition of "environment." In fact, the usual dependent variables in
behavioral experiments are activity variables.

If a given phenomenon meets the criteria both of an environmental phenomenon and of a behavioral phenomenon in terms of the above definitions, the phenomenon is defined as being subsumed under environment rather than activity. For example, suppose that rats in an experimental group receive a food pellet for pressing a lever, whereas pressing the lever yields no food for a control group otherwise subjected to the same procedure as is the experimental group. The treatments might then be designated as "dispensation of zero pellets for a lever press" and "dispensation of one pellet for a lever press." In this example the muscular contractions required for lever pressing are necessary for the treatments, but the treatment variable, the amount of food dispensed for a lever press, would be considered an environmental variable if it affected activity. The nature of such effects will be discussed in S. IA-3.1.

An animal's behavior is defined as those of the animal's activities that are affected by the animal's environment. Therefore, since an individual animal's environment does not alter the animal's genotype, an environmental effect on behavior is necessarily an effect that occurs above and beyond any genotypic effects on the animal's activity, although of course environment and genotype interact in determining behavior. Therefore, since phenotypic traits by definition represent phenotypic effects, the term "response," defined as a behavioral phenomenon, is demarcated in its meaning from the term "phenotypic trait." Yet environmental ef-
ffects on responses are largely analogous to environmental effects on genotypic and phenotypic traits in evolution, as will be discussed in S. IA-4.6 and elsewhere.

The above definition of "environment" indicates that environmental phenomena include only those phenomena that can be affected by an explicit source such as an experimenter's activity in particular. Whether such an effect "can" occur may vary from one situation to another. A given variable may thus be appropriately designated as environmental in one given or implied frame of reference but not in another. The distinction between environment and activity or behavior is thus a relativistic conception.

IA-1.3. Behaviorism

Pavlov (1928) wrote:

Does not the eternal sorrow of life consist in the fact that human beings cannot understand one another, that one person cannot enter into the internal state of another? . . . In our "psychical" experiments on the salivary glands . . . , at first we honestly endeavored to explain our results by fancying the subjective condition of the animal. But nothing came of it except unsuccessful controversies, and individual, personal, inco-ordinated opinions. We had no alternative but to place the investigation on a purely objective basis . . . , to concentrate our whole attention upon the investigation of the correlation between the external phenomena and the reaction of the organism [p. 50].

Today only mechanistic behaviorism as opposed to anthropomorphic mentalism is generally considered to be a scientifically valid approach to studying animal behavior. However, rigorously scientific thinking does not necessitate petty semantic nit-picking, and certain words with anthropomorphic connotations thus have de-
veloped scientific behavioristic usages. For example, certain words such as "learning," "hunger," and "fear," all defined in Part IA, have developed behavioristic usages that are more or less standard in the current experimental literature on animal behavior. As long as such usage is unambiguous, it is not invalid simply because one can be introspectively aware of learning, hunger, fear, and so on as conscious phenomena. Thus, in behavioral science the mnemonic practice has been followed of giving operational meaning to already existing words, as was done with words such as "force," "energy," and "work" in physics.

Any theories discussed herein will be in strictly behavioristic terms as opposed to being inferential or "black box" theories involving hypothetical constructs, intervening variables, and the like. The problem with inferential theories is that they have not generally been any more helpful than the more rudimentary and straightforward behavioristic theories as tools for predicting animal behavior. The nature of inferential theories and the process of establishing them have been summarized by Miller (1961):

We have great confidence in the electron as an intervening variable, because electrons produced by a great variety of experimental operations: rubbing a cat's fur against amber, heating a metal in a vacuum, putting zinc and carbon in acid, or cutting a magnetic field with a wire, all have exactly the same charge when measured by a variety of techniques—repelling like charges on a droplet of oil, depositing silver in an electroplating bath, or creating magnetic lines of force when they move. It is this kind of agreement which gives us confidence.

In the behavioral sciences we need to make much more use of such cross-checking of hypotheses [p. 747].
Unfortunately, many behavioral theories, both inferential and noninferential, have not been sufficiently based on such cross-checking (e.g., cf. Miller, 1961). D. J. Lewis (1960), in considering certain behavioral theories, aptly stated that "the longevity of a theory is apparently inversely related to the specificity with which it can be stated and tested [p. 17]." A too-common practice in many areas has been to theorize without first examining the actual behavior to which such theorizing is intended to apply, as D. J. Lewis (1960) pointedly observed after reviewing the literature in one such area:

Not many experimenters seem to be interested in how one variable relates to another along the major range of both variables. Most experimenters are interested in "theory" testing. As a result we have a large number of two or three group experiments, using a widely different array of apparatus, . . . telling us that our theoretical notions are largely inadequate, but not telling us a great deal more. . . . A theory ought to be about something, and parametric data make a wonderful subject matter [pp. 23-24].

Granting that mindless data collecting is no substitute for truly insightful theorizing, experimental findings are necessarily permanent unlike theories and often turn out to be of more lasting interest than do the theoretical interpretations originally used to pigeonhole the findings. Therefore this thesis will particularly emphasize findings, and restraint will be exercised in promulgating theories. No attempt will be made to consider all the theoretical interpretations originally given for the findings cited herein, since doing so would expand the discussion beyond manageable limits and is largely unnecessary in that experimental re-
sults often speak for themselves and speak more eloquently than do their theoretical interpretations.

IA-1.4. **Dimensions and Magnitudes of Stimuli and Responses**

The subject of stimulus-response relationships cannot logically be separated from the precepts for making the observations from which such relationships are derived. Thus, before proceeding to the main subject, stimulus effects on responses, it will be helpful to consider some basic concepts and terminology relating to evaluation and characterization of stimuli and responses. Stimuli and responses are evaluated, if at all, along "dimensions." A *dimension* of a stimulus or response is any type of measurement or classification scale appropriate to the stimulus or response.

For example, voltage is a dimension of electric shock but not of reflected light. Albedo and color are dimensions of reflected light but not of electric shock or of tones. Pitch and loudness are separable dimensions of tones. Electric shock, light reflected from the surface of experimental apparatuses, and tones are all stimuli commonly of interest in behavioral experiments. Volume per unit time is a response dimension for salivation but not for running. Countless additional examples of stimulus dimensions and response dimensions could be given, but the above examples should suffice to make the meaning of the word "dimension" clear.

The generic terms *stimulus magnitude* and *response magnitude* will herein designate any value or values along a given stimulus dimension or response dimension respectively. Stimulus magnitude
on a physical energy scale is often called stimulus intensity. Stimulus magnitude and response magnitude are constants at any one time for any individual animal or for any single group of animals but may be nonconstant variables in comparisons between or within individuals and groups.

Any variable predicated between animals is commonly called a "parameter." More generally, the term parameter generically denotes both of the following: (a) any independent variable that is either a treatment variable or a classification variable, as opposed to a chronological variable, and (b) any dependent variable regarded as a function of independent variables that are parameters. The word "parameter" may denote constants as well as variables having more than a single variate.

Response magnitude along some dimensions can be dealt with as a continuous function of time and can then be called the state of the response. For example, if running velocity, salivary flow, and skin conductivity are dealt with as continuous functions of time, each of these three variables may be generically referred to as the state of a response. In some cases response magnitude is not a continuous function of time, as discussed later in S. IA-2.2.

The identity of an individual stimulus or response can be specified in terms of an individual animal, a particular time, and a particular stimulus magnitude or response magnitude. However, the words "stimulus" and "response" in the singular will generally refer herein, as elsewhere, to subsistents as opposed to existents. Thus, for example, "a stimulus" can mean a stimulus pre-
sented to each individual in a specified group, and/or a stimulus presented at different specified times, and/or a stimulus whose magnitude varies along a specified dimension. For instance, whereas low- and high-pitched tones, say, can be regarded as different stimuli in relation to a specified loudness dimension or to no specified dimension, they might be regarded as the same stimulus in specified relation to a pitch dimension. Whenever stimulus magnitude or response magnitude is referred to herein as having a zero value, the stimulus or response is absent or not occurring in the situation being considered.
Chapter 2

RESPONSES

IA-2.1. Occurrence and Performance of Responses

"Occurrence" of stipulatory responses is a conception that will be useful shortly in discussing stimulus effects on responses. Thus, since some conundrums are involved in the matter of how and why a given response should be considered to have occurred, it will be helpful to discuss this matter now. The conundrums become evident in the following example.

Suppose that skin conductivity, say, is measured as a continuous function of time. A stipulatory response could then be said to occur whenever skin conductivity exceeded a criterion value of zero. This criterion is arbitrary except insofar as it satisfies our usual notions about what the word "occurrence" should mean. However, since skin conductivity always exceeds zero, a response by this criterion would always be occurring. Occurrence of this response would thus be a vacuous conception.

The only way to resolve this and comparable problems is for the criterion for occurrence to be an arbitrary level or range within the expected range of variation of response state. Thus, in the present example a response could be said to occur when skin conductivity is above or else below an arbitrary criterion level or when skin conductivity is within some criterion range, in which cases the occurrence of this response would continue over some time interval as opposed to being instantaneous. Alternatively,
this response might be said to occur instantaneously as skin conductivity rises above and/or falls below a criterion level.

Response state on a graded scale may thus be transformed to an all-or-none scale with occurrence of the response being the "all" and with nonoccurrence of the response being the "none." Such an all-or-none scale inherently provides less information than does the graded scale. Considering therewithal that responses can be said to occur only by arbitrary criteria, the question arises as to what purpose is served in establishing a criterion for occurrence of a response.

Defining occurrence of responses has a purpose beyond simply specifying what is to be recorded. This purpose emerges in view of the concept of "performance." The word performance generically denotes any variable that signifies how readily any given response occurs. Much of this chapter will be concerned with operational criteria for evaluating performance, and later it should become apparent that the concept of performance is of fundamental importance, behaviorally and biologically (cf. S. IA-4.7).

A stimulus effect on performance may be part of a feedback cycle between the stimulus and occurrence of the response for which performance is noted, as will be illustrated in S. IA-3.1. Such an effect on performance can be considered in relation to the feedback mechanism per se and can thus be abstracted from the particular criterion for occurrence of the response. However, in order to evaluate performance, and in order to design a procedure whereby occurrence of the response affects the stimulus and thus
engages in such feedback, occurrence of the response must be stip-
ulatively defined. Defining occurrence of responses is thus essen-
tial in investigating stimulus effects in relation to feedback
systems per se, and experiments concerned with such effects are
the empirical foundation for much of Part I.

IA-2.2. Response Amplitude

The operational nature of performance can best be explained
in relation to what will herein be called "response amplitude."
For present purposes the term response amplitude is defined as re-
sponse magnitude when response magnitude is not dealt with as a
continuous function of time. The expression "response amplitude"
thus refers generically to any variable expressed in such terms
as, say, average skin conductivity over some time interval, total
salivary volume over some time interval, or average running veloc-
ity with which an animal placed in a start box runs to the goal
box of a runway apparatus. In general, whereas response state by
definition is a continuous function of time per se, response am-
plitude is a function of successive time intervals or occasions.
This thesis is primarily concerned with experimental paradigms in
which the dependent variable is response amplitude and the inde-
pendent variable is stimulus magnitude.

Since response amplitude by definition is not a continuous
function of time, response amplitude has a necessarily finite num-
ber of variates (elemental values) within a given period of time.
In contrast, response state has an infinite number of instantane-
ous variates over a given time interval, since response state by
definition is a continuous function of time. In other words,
whereas response state represents analogical information, response
amplitude represents digital information. The generic term "re-
response magnitude" is synonymous with either of the less inclusive
generic terms "response state" and "response amplitude."

As indicated in the preceding section, occurrence of a given
response is all-or-none in terms of response state, i.e., in
terms of analogical information. Therefore, since performance is
defined in terms of occurrence of some given response, performance
as a graded (vs. all-or-none) variable must be evaluated as digit-
al information, viz., as response amplitude. "Performance" could
thus be defined as response amplitude when response amplitude ex-
plicitly signifies how readily a given response occurs. However,
whereas performance necessarily takes the form of response ampli-
tude, response amplitude does not necessarily take the form of
performance. The term "performance" is thus a less inclusive ge-
eric term than is the term "response amplitude."

Performance of a given response can be expressed as duration
of occurrence of the response per unit time interval if occurrence
of this response can continue over some time interval as opposed
to being instantaneous (cf. S. IA-2.1). On the other hand, if oc-
currence of a given response can be regarded as instantaneous,
performance takes the form of either "response frequency" or "re-
response speed." These two types of performance will now be dis-
cussed in turn. At the same time, some common and convenient terms
relating to response frequency and response speed will be intro-
duced.

IA-2.3. Response Frequency

To begin with an example, a lever press may be regarded as
essentially instantaneous insofar as it is recorded without regard
to how hard or for how long the lever is pressed. Thus, for in-
stance, the usual commercial equipment for automatically recording
lever presses is sensitive only to the leading edge of the elec-
trical pulse produced by lever depression. Response frequency—in
this case, the frequency of lever pressing—can then be measured
as the number of lever presses per fixed length of time.

In this example, response frequency has no definite upper
limit. In such cases response frequency is often called response
rate. In other cases, however, an upper limit may exist. For exam-
ple, suppose that an animal is placed in the stem of a T-maze ten
times each day and is removed from the apparatus after running to
one of the arms of the T-maze. In this case response frequency may
be measured, for example, as the daily proportion of runs to the
left arm. Response frequency might then be called choice perform-
ance for a particular side, the left side in this example.

Performance might instead be given simply as the side to
which more runs occur. In this case performance is called prefer-
ence for that side. The terms "choice" and "preference" apply to
any paradigm analogous to a T-maze paradigm, although the use of
these terms is not restricted to cases where only two alternative
responses are involved as in a T-maze.

Preference can be quantitated rather than being given simply as a comparative evaluation of the sort described. Quantitative preference is not synonymous with choice performance. In S. IB-2.3 the measurement of preference will be described in reference to a particular experiment.

IA-2.4. Response Speed and Latency

Response speed is the mathematical inverse of what is called response "latency." The word latency denotes the time interval elapsing before a response occurs. Since this interval must be measured from some initial point in time, the measurement of latency must incorporate a criterion stating when this point in time occurs. For instance, in the example of lever pressing as discussed in the preceding section, the time interval between any two successive lever presses can be called the latency of occurrence of the second response.

To take some additional examples, latency can be measured for shuffling, or locomotion from one compartment to the other in a shuttlebox, a two-compartment apparatus. Latency for a shuttle response could be measured either from the time of onset of a stimulus, e.g., a tone, or from the time at which the previous shuttle response occurred. If the response under consideration is leaving the start box or entering the goal box of a runway apparatus, response latency could be measured from the time when the animal involved is placed in the start box of the runway. Alternatively, if
the response under consideration is entry into the goal box, response latency could be measured from the time when the animal leaves the start box. If the speed of this response is multiplied by the distance between the start box and the goal box, the transformed value of response speed is average running velocity between the start box and the goal box.

In behavioral experiments the measured speed of a response has a lower limit that is greater than zero and that is fixed by procedural specifications. For example, since animals cannot be left in a runway apparatus for an indefinite length of time, an animal might be taken out of the apparatus if it does not enter the goal box within, say, 60 sec. after being placed in the start box. In this case the lower limit of response speed is \( \frac{1}{60} \) sec.\(^{-1} \) if the response occurs within the 60 sec. allowed. If the response does not occur within the 60 sec., response speed could perhaps be approximated as zero in that measured response speed would have been less than \( \frac{1}{60} \) sec.\(^{-1} \) had more time been allowed.

IA-2.5. Occasions for Measuring Performance

It will be enlightening to discuss explicitly what types of conditions delimit an occasion for obtaining a performance measurement under experimental conditions. When does such an occasion begin, and when does it end? It is fitting first to dispose of the simpler question as to when an occasion for obtaining a single performance measurement ends. The answer can be culled from the two preceding sections: Such an occasion ends either when a re-
sponse occurs or when a predetermined length of time has elapsed since the occasion began.

As for when an occasion for measuring performance begins, the discussion in the two preceding sections suggests three alternative types of criteria that fix the initial point in time.

1. An occasion for obtaining a single performance measurement may begin with presentation of a stimulus, as will be discussed more fully in Ch. 5, Part IA. As a special case, an occasion for measuring performance may begin when an animal is placed in an apparatus, e.g., a runway apparatus, as discussed in the preceding section. In this case the start box of the runway is the stimulus.

2. The initial point in time may be when a specified response occurs, e.g., when an animal leaves the start box of the runway, as was indicated in the preceding section.

3. An occasion for obtaining a single performance measurement may begin at the end of a previous such occasion. For example, if lever pressing rate is determined for each of a series of successive time intervals, all these time intervals except the first begin at the end of the previous time interval.

Performance can be measured by methods other than those described, but these other methods are basically similar to those methods described in the preceding sections. For example, choice performance might be evaluated as the inverse of the proportion of "incorrect" choices rather than being evaluated as the proportion of given or "correct" choices as described earlier in S. IA-2.3. These two methods of evaluation are basically similar in that the
difference between them is only a matter of the type of scale used. Responses besides those already considered will be discussed later at various points, and further examples of performance will be given as the need arises.

IA-2.6. Experimental Phases and Groups

Various experiments from the literature will be described and discussed beginning in Part IB. Experiments are often divided into consecutive phases between which the procedure is altered. In describing various experiments consecutive numerals will be used herein to designate consecutive phases, and numerals will also be used to designate groups of animals (subjects), wherever and however doing so facilitates the discussion. The words "phase" and "group" will frequently be abbreviated as "ph." (plural "phs.") and "g." (plural "gs."). Procedurally, animals are treated individually rather than collectively in such experiments as will be considered herein, but groups will commonly be mentioned inasmuch as group averages and procedural uniformities within groups are the integrants of such experiments.

In order to discuss various factorial experiments with a minimum of confusing verbiage, groups of subjects will be designated as follows. In a $2^2$ factorial experiment, the two main groups between which one stated factor is varied will be designated as "G. 10" and "G. 20" respectively in conjunction with the specified "low" and "high" treatment levels of that factor. Similarly, the two main groups between which the other factor is varied will be
designated as "G. 01" and "G. 02" in respective correspondence to the specified "low" and "high" treatment levels for this factor. The four subgroups, "10 and 01," "10 and 02," "20 and 01," and "20 and 02," will be designated respectively as Gs. 11, 12, 21, and 22.

The sign (positive or negative) for any main effect or interaction will be based on the designation of treatment levels as "low" and "high" and will be given in accordance with convention. For example, in comparing Gs. 10 and 20, a sample estimate of the main effect is evaluated as response amplitude for the "high" treatment level group (always 20) minus response amplitude for the "low" treatment level group (always 10); a sample estimate of interaction is evaluated as the combined (e. g., average) response amplitude for Gs. 11 and 22 minus the combined response amplitude for Gs. 12 and 21; etc. (e. g., cf. Snedecor & Cochran, 1967, S. 12.2). With factorial designs involving more than two factors or treatment levels per factor, groups of subjects will be designated respectively by more than two digits or by numerals higher than 2 where appropriate. Although this terminology would have to be modified slightly for experiments with 10 or more main groups under any factor, there will be no occasion to have to do so herein.
Chapter 3

STIMULI

IA-3.1. **Stimulus Magnitude as a Treatment Variable**

In S. IA-1.2 it was said that an animal's environment in behavioral experiments is whatever phenomena and events can affect the animal's behavior and can be affected in turn by the investigator's conduct of experiments. Therefore, to recall the definition of "stimulus" in S. IA-1.1, stimulus magnitude in a behavioral experiment can be construed as any given treatment variable (but not any other type of independent variable) affecting response magnitude. Although such a concept of stimulus magnitude is quite broad, this fact has little bearing on the scope of this thesis because the concern of this thesis is not with cataloguing stimulus-specific effects, but with discussing basic principles as was indicated in S. IA-1.1.

More specifically, this thesis will be concerned with basic principles that pertain to stimulus effects on response amplitude. Some fundamentals concerning measurement of response amplitude were dealt with in the previous chapter. Now it is appropriate to turn to a matter more directly germane to the main theme of this thesis: how stimulus magnitude as a treatment variable may be experimentally manipulated to affect response amplitude.

Some essential issues involved can be deduced from the following hypothetical experiment. Suppose that every animal in control and experimental groups is food-deprived and is given two trials,
each of which consists of placing an animal in the start box of a runway apparatus and recording response amplitude (performance) as speed of entry into the goal box. Also, in terms of the procedure for this hypothetical experiment, the only systematic difference between the two groups is that the animals in the experimental group are presented with food upon entry to the goal box, whereas the animals in the control group are not. The animals in both groups are allowed to remain in the apparatus for 60 sec. after entering the goal box, during which time the animals in the experimental group can eat. The postulated results of the experiment consist of four performance means, one for each group and trial. The Trial 2 mean for the experimental group is greater than the other three means, which do not differ significantly from each other.

In the above experiment the treatment variable was the amount of food presented—zero pellets vs., say, three pellets—for performing the requisite response, entering the goal box. Given that the postulated result was not fortuitous, the experiment showed that this treatment variable affected response amplitude, since response amplitude increased for the experimental group but not for the control group. The food was therefore a stimulus as defined in S. IA-1.1, and the treatment variable, the amount of food presented, could thus be designated as stimulus magnitude. The above experiment hypothetically showed, then, that stimulus magnitude affected performance under the conditions of the experiment.

In other words, the experiment demonstrated an empirical
stimulus-response relationship. Yet the procedure of the experiment was designed so that occurrence of the requisite response could affect the stimulus-food in that food presentation was contingent on occurrence of this response. To avoid possible confusion, such procedural contingencies will be consistently referred to herein as contingencies, whereas empirical stimulus-response relationships will be referred to by other expressions such as "stimulus-response relationships," "stimulus control of behavior," and "stimulus effects on behavior."

Note that the above experiment involved mutual causation, with a contingency pointing in one causal direction, and with a stimulus-response relationship pointing in the opposite direction. That is, for the experimental group, greater-than-zero performance on Trial 1 caused greater-than-zero food presentation on Trial 1, and greater-than-zero food presentation on Trial 1 was found to cause an enhancement of performance on Trial 2. The postulated experimental result was thus the end result of feedback between stimulus magnitude and performance (cf. Kramer, 1968). Additional trials beyond Trial 2 would have permitted additional rounds of the feedback cycle.

If response amplitude is modified because of the earlier presence of a stimulus, as in the hypothetical experiment described above, the increment or decrement in response amplitude constitutes what is commonly called learning. This definition involves a conundrum: On what grounds can the presence of a stimulus be regarded as being in the past? For example, with regard to the
hypothetical experiment above, on what grounds can it be said that response amplitude was modified because of the earlier presence of food in the goal box rather than the transient ongoing presence of food in the gut?

Generally in experiments on learning, an attempt is made to minimize the possibility that learning reflects such transient and trivial effects, whether they be due to changes occurring internally or externally to an animal. Thus, if the above experiment were actually carried out, Trials 1 and 2 might have been timed rather far apart if food in the gut were considered likely to increase response amplitude. Aside from the issue of transient effects, the presence of a stimulus can ultimately be judged only on an operational basis. Thus, operationally, the food stimulus in the experiment described was present when and only when the experimenter presented it to the animals.

IA-3.2. **Stimulus Magnitude as an Operational Variable**

Stimulus magnitude is, essentially, some variable that quantitates the presence of some stimulus along a given dimension and must therefore, like the presence of a stimulus, be judged on an operational basis. For example, stimulus magnitude might be identified as the voltage of electric shock and might then be determined with a voltmeter or by the position of a dial controlling circuit resistance. Such physical methods of determining stimulus magnitude have shortcomings that are perhaps obvious.

For example, animals being shocked are likely to urinate and
to defecate on the shock grid. The urine can then produce resistance changes in the shock circuit, and the fecal boluses might short-circuit adjacent grid wires. Other uncontrollable factors include, for example, how much body surface is in contact with the grid, the sensitivity of the parts of the body in contact, and behavior such as jumping that affects exposure to the shock. Yet physical determination of shock intensity cannot take all such factors into account and will therefore not correspond precisely with any behavioral effect.

To consider another example, suppose that stimulus magnitude is to be evaluated as the brightness of an illuminable window in an experimental apparatus. Now an experimenter would be somewhat limited in his ability to control whether an animal looks at the window. The brightness of window illumination may thus correspond poorly with any behavioral effect.

Nevertheless, in cases such as these, stimulus magnitude does have an unbiased relationship to any behavioral effect as long as the subjects involved are representative of the population of interest. However, as the above examples illustrate, such a relationship may be subject to considerable random error between individual animals. Such error is undoubtedly an important reason why the "signal-to-noise" ratio often appears to be low for stimulus-response relationships.

In the preceding section it was said that stimulus magnitude can be regarded as any given treatment variable affecting response magnitude in a behavioral experiment. On this basis the expression
"stimulus magnitude" can apply, for instance, to food deprivation in that the magnitude of food deprivation can serve as a treatment parameter and as such can affect response magnitude as described later in S. IB-1.4 and elsewhere. The magnitude of food deprivation can be evaluated as parametric deprivation time after an animal has been allowed to eat ad lib, or as the amount of food that an animal consumes after deprivation, or as a body weight loss due to food deprivation (e.g., see Black, 1965). When operationally defined in such a manner, food deprivation is commonly called hunger. Water deprivation analogously defined is called thirst.

Experimental evidence would appear to indicate that hunger, for example, results in internal chemoreception (e.g., cf. Code, 1967; Morgane, 1969; Morgane & Jacobs, 1969) and on this basis constitutes what might be regarded as a stimulus of internal origin. However, the origin of a stimulus cannot really be specified—a stimulus reaching a receptor comes from somewhere else, and so on back—and, as the foregoing discussion implies, the concept of hunger magnitude is noncommittal with regard to whether hunger originates internally or externally. In general, variables such as stimulus magnitude and response magnitude are abstractions and as such have no physical location or place of origin.

IA-3.3. Classification of Stimuli

Stimuli can be classified in terms of physical effects or in terms of what sensory modalities stimuli affect. For example, in terms of physical effects, stimuli may be classified as electro-
magnetic, acoustical, chemical, pressural, thermal, gravitational, etc. In terms of sensory modalities, stimuli may be classified as visual, audile, olfactory, gustatory, tactile, thermal, baroreceptive, vestibular, proprioceptive, etc.

One might think that stimuli could also be classified somehow in terms of behavioral effects beyond the sensory or afferent level. Such a classification, like any type of classification, would serve the useful purpose of delimiting and accentuating similarities and differences within the system of classification. However, since a given stimulus may affect a great and diverse variety of responses, and since a great and diverse variety of stimuli may affect a given response, classification by physical effects or by sensory modalities does not serve as an adequate basis for constructing a broad classification of stimuli in terms of behavioral effects.

However, for any given response stimuli may readily be classified as to their behavioral effects in relation to contingencies. Such a classification is given in T. IA-3.3. In the succeeding chapters the terms in this table will be defined in a way that largely corresponds with common usage in current behavioral literature, except that the terms "drive-incentive," "forfeit-incentive," "forfeit," and "feedback stimulus" are original as defined herein. The acronyms in T. IA-3.3 are conventional in behavioral literature.

The categories indented in T. IA-3.3 represent hierarchical subcategories. For example, in T. IA-3.3 a reward is one type of
<table>
<thead>
<tr>
<th>TABLE IA-3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEHAVIORAL CATEGORIES OF STIMULI</td>
</tr>
<tr>
<td>Incentive</td>
</tr>
<tr>
<td>Reward</td>
</tr>
<tr>
<td>Punishment</td>
</tr>
<tr>
<td>Drive-incentive</td>
</tr>
<tr>
<td>Forfeit-incentive</td>
</tr>
<tr>
<td>Drive and forfeit</td>
</tr>
<tr>
<td>Cue</td>
</tr>
<tr>
<td>Positive cue ((S^+ \text{ or } S^D))</td>
</tr>
<tr>
<td>Negative cue ((S^- \text{ or } S^A))</td>
</tr>
<tr>
<td>Feedback stimulus</td>
</tr>
<tr>
<td>Unconditioned stimulus ((US \text{ or } UCS))</td>
</tr>
<tr>
<td>Conditioned stimulus ((CS))</td>
</tr>
<tr>
<td>Positive conditioned stimulus ((CS^+))</td>
</tr>
<tr>
<td>Negative conditioned stimulus ((CS^-))</td>
</tr>
<tr>
<td>Habituatory stimulus</td>
</tr>
</tbody>
</table>
incentive, and an incentive, in turn, is one type of stimulus. Any applicable term in the hierarchy may be used to refer to a given stimulus. For example, if a given stimulus is a reward, the magnitude of this stimulus may be referred to as stimulus magnitude, incentive magnitude, or reward magnitude. Likewise, incentive learning, a term defined later in § IA-4.2, can be designated reward learning if it refers to an incentive that is a reward, and so forth.

IA-3.4. The Nature of the Behavioral Categories of Stimuli

Any given term in T. IA-3.3 generically denotes any stimulus that has a particular role in one of two general types of learning paradigms, designated "training paradigms" and "conditioning paradigms." Each of these paradigms is defined in terms of two criteria that specify the following, respectively: (a) contingencies, if any, between responses and stimuli, and (b) the effect of such stimuli on response amplitude. The terms in T. IA-3.3 are thus defined in terms of the roles that stimuli have in relation to these criteria.

Experimentally, the first of these two criteria is a matter of experimental design, and the second is a matter of stimulus effects on response amplitude within the experimental design. Hence, the terms in T. IA-3.3 are defined in terms of how stimuli affect behavior within various types of experimental design. Thus, the only logical requirement for these definitions is that such effects be logically possible.
However, before these definitions can be applied empirically, they must be documented in such a way as to show that such logically possible effects actually occur empirically. Such documentation will be adequately provided in Part IB. Once documented, the classification system in T. IA-3.3 will provide a useful and convenient vehicle for systematizing many simple and complex experimental results concerned with behavioral effects of stimuli. The remainder of Part IA will be concerned with constructing the logical framework for the empirical discussion in Part IB.

As mentioned above, the terms in T. IA-3.3 are defined in terms of the roles that stimuli have in relation to experimental design and response amplitude within the experimental design. The physical or sensory nature of a stimulus thus bears no a priori relationship to the behavioral category into which a stimulus falls. Thus, for example, electric shock can be a reward (e. g., see S. IB-10.7), a punishment (e. g., see S. IB-1.3), a drive (e. g., see S. IB-1.4), a cue (e. g., cf. S. IB-4.5), a feedback stimulus (see Ch. 5, Part IB), an unconditioned stimulus (e. g., see S. IB-8.4), a conditioned stimulus (e. g., see S. IB-6.1), or a habituatory stimulus (e. g., see S. IB-9.4).

Moreover, a given stimulus may fall within two or more categories at the same time. This is true for physical and sensory categories as well as for behavioral categories. For example, an object regarded as a stimulus can have both visual and tactile properties. Similarly, the main behavioral categories (incentive, cue, etc.) in T. IA-3.3 are not necessarily mutually exclusive.
For example, shock can simultaneously be a conditioned stimulus and an incentive (see S. IB-10.7); food can simultaneously be an incentive and a cue (see S. IB-4.1); and so forth. In such cases, when a stimulus falls into more than one category, the categorization scheme in T. IA-3.3 becomes especially helpful in sorting out generalities.
Chapter 4

TRAINING: INCENTIVES

IA-4.1. Training Paradigms

Any training paradigm has the following two definitive features, each of which is a respective case of the two criteria given in the last section of the preceding chapter.

1. Either appearance (presentation, onset) or disappearance (termination, removal, offset) of some stimulus is systematically contingent on either occurrence of some response or failure of some response to occur.

2. This stimulus either enhances or diminishes performance (the amplitude) of this response systematically in association with this contingency if performance is measured under those environmental (procedural) conditions in which the contingency has been in effect on previous occasions.

In order to make this definition as clear as possible, the following points should be made. A training contingency can be explicitly "systematic" only in reference to a control treatment for which the contingency does not apply, and a stimulus effect must be evaluated relatively to such a control treatment in order to say that this effect occurs "systematically in association" with a contingency as the above definition states. The nature of such controls will be discussed in Ss. IA-4.2, IA-4.4, and IA-5.2. Even if such controls be omitted in practice because they would be trivial (see S. IA-4.2), a contingency as described would have to
be at least implicitly systematic for the word "training" to apply. If appearance or disappearance of a stimulus is contingent on "failure" of a response to occur, this means, in other words, that occurrence of the response prevents the stimulus from being presented or terminated.

As the definition of training indicates, performance in a training paradigm is measured under the same procedural conditions in which the training contingency has been in effect, at least under experimental as opposed to control conditions. Hence, under experimental conditions an occasion for obtaining a performance measurement is procedurally the same as and may be simultaneous with an occasion on which a training contingency potentially affecting subsequent performance is in effect. As was stated in S. IA-2.5, any single performance measurement is made on an occasion ending either with occurrence of a response or at a given time. Hence, the same applies to an occasion on which a training contingency is in effect. Thus, on any given occasion the requisite occurrence or nonoccurrence of a response must fall within a given time interval in order for the contingency to be fulfilled on that occasion.

For example, suppose that the stimulus referred to in the above definition is food in the goal box of a runway apparatus, and that the criterion response consists of an animal's entering this goal box after having been placed in the start box of the apparatus. Now the animal might be taken out of the runway if this response does not occur within, say, 60 sec. after placement of
the animal in the start box, as was discussed in S. IA-2.4. Occurrence of this response must thus fall within a given 60-sec. time interval in order for the animal to be presented with the food.

By definition of "contingent," response-contingent appearance of a stimulus must follow occurrence of the prerequisite response. Similarly, appearance of a stimulus must follow a criterion time for nonoccurrence of a response that fails to occur as required for appearance of the stimulus. Hence, in these two cases, since an occasion for measuring performance can end with response occurrence or at such a criterion time, the stimulus does not have to be operationally present as performance is measured. Thus, if the stimulus affects performance as specified in the definition of training, it is not implied that performance must be measured in the presence of the stimulus. The stimulus can still affect performance in relation to a control treatment whereby the stimulus is not presented at all, as discussed in the next section and in Part IB.

Disappearance of a stimulus is the opposite case to that just discussed regarding appearance of a stimulus. If disappearance of a stimulus is contingent on occurrence of a response, the existence of the contingency indicates that the stimulus is present before that response occurs. Similarly, if disappearance of a stimulus is contingent on nonoccurrence of a response, the stimulus must be present before a criterion time for nonoccurrence of this response. Thus, in these two cases, insofar as an occasion for measuring performance is procedurally the same as an occasion on
which a training contingency is in effect, as discussed above, such a stimulus must be present during any time interval over which performance is measured. In fact, an occasion for measuring performance would typically begin with presentation of such a stimulus.

If stimulus presentation or termination is contingent on occurrence of a response, the stimulus might have to be presented or terminated eventually even if the response does not occur while the contingency is in effect. For example, if the stimulus is electric shock subject to termination by a lever press, the shock might have to be terminated eventually even if no lever press occurs when required. In such cases the definition of training does not preclude the possibility of noncontingent presentation or termination of the stimulus once the training contingency is no longer in effect.

However, suppose that a response occurs when stimulus presentation or termination is contingent on nonoccurrence of a response. In this case the stimulus cannot be presented or terminated noncontingently until some time after the stimulus would have been presented or terminated in fulfillment of the contingency. Otherwise, no contingency would exist.

IA-4.2. Incentives

As mentioned in the definition of training, the stimulus appearing or disappearing through the training contingency either enhances or diminishes performance. If performance is thus affect-
ed by virtue of this contingency, the stimulus is called an incentive. This definition implies that a stimulus may be characterized as an incentive with the following paradigmatic training procedure.

On repeated occasions the stimulus is presented or terminated contingently on occurrence or nonoccurrence of some response for an experimental group but not for a control group. For the control group the stimulus is presented or terminated only if and when the stimulus would be presented or terminated failing prerequisite occurrence or nonoccurrence of the target response in the corresponding experimental group (cf. S. IA-4.1). The occasions for measuring performance begin according to some criterion that is identical between the groups (cf. S. IA-2.5), and, ideally, the operational presence or absence of the stimulus is uniform between the groups as performance is measured. In short, the only procedural difference between the groups is the experimental group's contingency. Any reliable performance difference between the groups thus indicates a stimulus effect occurring by virtue of this contingency. The stimulus is therefore an incentive by definition.

Thus, for example, the stimulus food is an incentive in the hypothetical runway experiment that was discussed in S. IA-3.1. In discussing that experiment it was noted that the postulated behavioral effect of this stimulus occurred through a feedback cycle, and the same applies to incentives generally. Incentive effects can be evaluated within groups as well as between groups, as will
be discussed in S. IA-5.2. The concept of incentives could be extended to procedures with response state rather than performance as the dependent variable. However, incentive effects have mainly been investigated in terms of performance, and incentive effects on response state are thus beyond the scope of the present discussion.

An incentive effect on performance cannot be due to the ongoing presence of the incentive if the incentive is uniformly absent or present between control and experimental groups, as indicated above, when performance is being evaluated. Thus, an incentive effect on performance must be due to the earlier presence of the incentive. Hence, by the definition of "learning," an incentive effect on performance constitutes learning for the target response. Such an effect is therefore called incentive learning.

Any training procedure results in a stimulus effect on performance of the target response, since only then is the procedure designated as training by the definition of training. Incentive training therefore results in an incentive effect on performance of the target response. Hence, since such an effect constitutes learning, incentive training by definition results in learning of the target response.

A stimulus used in training may be characterized as an incentive without a control procedure of the sort described if such a procedure would be trivial. For example, suppose that a performance increase occurs in conjunction with a response-stimulus contingency. The experimenter, from his general knowledge and experi-
ence, may believe that such an increase would be unlikely with the appropriate control procedure, whereby this contingency would not be in effect. The observed performance increase in itself would then constitute prima facie evidence that the response-contingent stimulus in an incentive. On a relative basis incentive learning can be compared among different incentives or incentive magnitudes for separate experimental groups without any control procedures if the control procedures for each of these groups would be mutually identical.

Suppose that the paradigmatic procedure described above is followed by a second phase in which the procedure for all the animals is uniformly the same as the control procedure of the first phase. Performance for the experimental group might then be expected to revert toward the control or base-line level of performance. Such a performance change would constitute extinction, defined as a learning loss or reversion when the contingencies originally supporting learning have been discontinued (cf. S. IA-4.7). Since extinction itself can be construed as learning, learning prior to extinction training may be called acquisition in order to distinguish this initial learning from extinction. The term "incentive learning" as used herein will refer only to acquisition.

When an animal's performance reaches an extinction criterion --for example, a criterion of more than 60 sec. to enter the goal box of a runway apparatus--the experimental procedure may be discontinued for that animal; thus the reason for having an extinction criterion. The term resistance to extinction (Rn) for a group
denotes the average number of trials to criterion for the group. A group's performance on an extinction trial can be evaluated as average performance for those animals whose performance has not yet reached criterion.

IA-4.3. Types of Incentives

The definitions of "training" and "incentive" indicate that training paradigms involving incentives can be classified into eight logically possible categories based on the contingent event (incentive appearance vs. disappearance) x the response requirement for this event (occurrence vs. nonoccurrence of some response) x the resulting performance change (increase vs. decrease). This eight-fold classification is the basis for the four-fold classification of incentives that was shown in T. IA-3.3. As shown therein the four categories of incentives are reward, punishment, drive-incentive, and forfeit-incentive.

Each of these categories is associated exclusively with two of the eight possible types of training situations and is defined as an incentive in either associated type of situation. The specific definitions for the four incentive categories consist of the information in T. IA-4.3. The performance changes listed in T. IA-4.3 are for experimental treatments as compared to control treatments of the kind indicated in the preceding sections. Such performance changes constitute incentive learning as discussed in the preceding section.

Note in T. IA-4.3 that the eight sets of training conditions
### TABLE IA-4.3

**The Defining Characteristics of the Four Incentive Categories**

<table>
<thead>
<tr>
<th>Type of Incentive</th>
<th>Contingent event (incentive appearance vs. disappearance)</th>
<th>Response requirement for contingent event (occurrence vs. nonoccurrence of response)</th>
<th>Performance change due to contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reward</td>
<td>Appearance</td>
<td>Occurrence</td>
<td>Increase</td>
</tr>
<tr>
<td>Drive-incentive</td>
<td>Disappearance</td>
<td>Occurrence</td>
<td>Increase</td>
</tr>
<tr>
<td>Reward</td>
<td>Appearance</td>
<td>Nonoccurrence</td>
<td>Decrease</td>
</tr>
<tr>
<td>Drive-incentive</td>
<td>Disappearance</td>
<td>Nonoccurrence</td>
<td>Decrease</td>
</tr>
<tr>
<td>Punishment</td>
<td>Appearance</td>
<td>Occurrence</td>
<td>Decrease</td>
</tr>
<tr>
<td>Forfeit-incentive</td>
<td>Disappearance</td>
<td>Occurrence</td>
<td>Decrease</td>
</tr>
<tr>
<td>Punishment</td>
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<td>Nonoccurrence</td>
<td>Increase</td>
</tr>
<tr>
<td>Forfeit-incentive</td>
<td>Disappearance</td>
<td>Nonoccurrence</td>
<td>Increase</td>
</tr>
</tbody>
</table>
can be divided into four pairs within which only the contingent event differs between sets of conditions. Such a division into pairs underscores a basic similarity between the sets of conditions within each pair. This similarity can be seen by considering as an example the uppermost pair in T. IA-4.3. Within this pair the two sets of conditions differ from each other only insofar as appearance of a reward is the contingent event with one set of conditions, whereas disappearance of a drive-incentive is the contingent event with the other. In both cases, therefore, the contingent event is an environmental change. Thus, since conditions in both cases are otherwise mutually identical in terms of the information in T. IA-4.3, both sets of conditions are essentially similar. Analogous similarities exist for the remaining sets of conditions in T. IA-4.3. Note from T. IA-4.3 that an animal's behavior tends to select rewards and forfeit-incentives into the animal's environment and to select punishments and drive-incentives out of the environment.

The word "punishment" has another common meaning besides that given in T. IA-4.3. Namely, this word sometimes denotes an event, appearance of punishment as a stimulus. Attempts to conventionalize the behavioristic meaning of "punishment" have been unsuccessful (see Campbell & Church, 1969, Appx. A). Unless otherwise noted, the word "punishment" as used herein will mean punishment as a stimulus, i.e., punishment as defined in T. IA-4.3, not punishment as an event. The word reinforcement often is used to denote appearance of a reward (see also S. IA-6.7) and is thus analogous
to the word "punishment" referring to an event.

In demonstrating reward learning or punishment learning, the basic experimental procedure referred to in the preceding section involves contingent stimulus presentation at a positive magnitude and with 100% reliability, and, as indicated in the preceding section, the corresponding control procedure involves nonpresentation of the stimulus. Therefore, since nonpresentation of the stimulus amounts to presenting the stimulus at zero magnitude or with 0% reliability, the definitive comparison for demonstrating reward learning or punishment learning amounts to presenting a stimulus at two given points on each of the following dimensions: (a) the proportion of occasions on which the incentive contingency is in effect, and (b) incentive magnitude. An extension of this procedure would be to quantitate reward learning or punishment learning by presenting the incentive at more than two points along either one of these dimensions.

For example, with regard to the proportion dimension, an additional group (or additional groups) besides the usual experimental and control groups could be given what is commonly called partial reinforcement. This term denotes reinforcement under conditions whereby occurrence of the target response sometimes yields reward and sometimes yields no reward in an irregular sequence for each animal. In contradistinction to the expression "partial reinforcement," the procedures for the usual experimental and control groups are called continuous reinforcement and nonreinforcement.
IA-4.4. Drives and Forfeits

In T. IA-3.3 the terms "drive" and "forfeit" were presented as stimulus categories not subsumed under the "incentive" category. The expressions "drive" and "drive-incentive" are somewhat related to each other in meaning, as are the terms "forfeit" and "forfeit-incentive." These relationships between terms can be most clearly described by referring to the earlier discussion in S. IA-4.2. There it was indicated that a stimulus to be characterized as an incentive—in particular, as a drive-incentive or as a forfeit-incentive—is not terminated for a control group except under the stated conditions.

In contrast, a stimulus to be characterized as a drive or a forfeit is not presented to a control group in the first place. The procedure for the control group is thus the same as if the stimulus were to be characterized as a reward or a punishment. The procedure for the experimental group, on the other hand, is the same as if the stimulus were to be characterized as a drive-incentive or a forfeit-incentive.

Under these conditions the stimulus is a drive if performance by the experimental group exceeds the control group's performance. Conversely, the stimulus is a forfeit if the control group's performance exceeds the experimental group's performance. Note that the definitive procedure for identifying drives and forfeits does not indicate whether a drive or forfeit effect on behavior occurs by virtue of the fact that the target response terminates the pertinent stimulus. Hence, by the definition of "incentive," a drive
or forfeit is not an a priori incentive. Therein is the essential basis for distinction between the terms "drive" and "drive-incentive" and between the terms "forfeit" and "forfeit-incentive."

As was discussed in S. IA-4.2, any ongoing incentive effect on performance is due to the prior presence of the incentive, and for this reason any incentive effect constitutes learning. However, the reasoning developed in that section does not apply to drives and forfeits in that a drive or a forfeit is not uniformly absent or present when performance is compared between the experimental and control groups described above. Hence, any ongoing drive or forfeit effect on performance may be due to either the prior or the ongoing presence of the stimulus, or to both. The term "learning" is therefore not evidentially applicable to drive effects and forfeit effects as such. An alternative term for such effects is motivation.

T. IA-4.3 indicated four logically possible types of training paradigms involving drive-incentives and forfeit-incentives. Analogously, four types of training paradigms involve drives and forfeits. These four categories, along with the eight categories altogether in T. IA-4.3, make a total of twelve categories.

IA-4.5. Trained Responses

In S. IA-4.1 training paradigms were defined with reference to both stimuli and associated responses, and to such stimuli the terms "incentive," "drive," and "forfeit" have been applied. Now,
to complement the terminology, terms for these associated responses will be introduced. If an experimental group in a training paradigm demonstrates learning in relation to a control group, the learned response is called a trained response, an operant response, or an instrumental response. The term operant response often connotes a response evaluated in terms of response rate, whereas the term instrumental response often connotes a response that is quantitated in terms of response speed. A basis for the distinction is that an elemental performance value may reflect several "operant" responses but reflects no more than one "instrumental" response. However, the terms "operant response" and "instrumental response" may be used interchangeably.

In T. IA-4.3 incentives were classified by eight conceivable types of training paradigms. The associated performance changes, shown in T. IA-4.3, could be classified similarly, but terms reflecting such a classification are commonly used for only three of the eight categories. These terms are "passive avoidance," "active avoidance," and "escape" and are defined as follows.

The term passive avoidance denotes the performance decrease for any response whose occurrence has resulted in effective punishment. Active avoidance is the performance increase for any response whose nonoccurrence has resulted in effective punishment. Escape is the performance increase for any response whose occurrence has resulted in disappearance of a drive-incentive or drive. The term "escape" is not customarily applied in relation to deprivation stimuli, which are commonly investigated as drives (cf. S.
IA-4.6. Incentive Learning as a Darwinian Process

Suppose that incentive learning is to be assessed with experimental and control groups as described earlier in S. IA-4.2. Then, for the experimental group, a given response must occur or fail to occur as required for the contingent event, appearance or disappearance of a stimulus, to take place, or else the contingent event does not take place. But if the contingent event does not take place, then, according to S. IA-4.2, the experimental procedure for the two groups is identical. It follows a priori that performance cannot differ reliably between two such groups. Hence, from S. IA-4.2 the stimulus cannot act as an incentive, and incentive training cannot take place.

The crucial point is that incentives cannot be used to train an animal unless appropriate behavioral variation exists initially. This point suggests an analogy between incentive learning of responses and evolution of phenotypic traits. The essential features of biological evolution can be idealized in terms of three consecutive stages, each prerequisite to the next, whereby a taxon adapts to a given environmental factor:

1. Initial variation of phenotypic traits occurs among the elements (e.g., individuals, species) within the taxon.

2. Natural (or artificial) selection results in evolution, but only for (a) those phenotypic traits whose positive or negative survival value permits the relevant environmental factor to
change the incidence of those traits' survival from one generation to the next, and (b) other phenotypic traits whose survival is thereby affected through Darwin's (1872) "correlated variation."

3. Adaptation occurs in that the incidence of survival tends toward an equilibrium level for any phenotypic trait under steady-state conditions of natural selection.

Point by point, the following analogy compares an individual's responses with a taxon's phenotypic traits.

1. As discussed above, initial variation of a given response is prerequisite for incentive training directed toward that response. Various factors affecting initial response variation will be discussed in S. IB-3.3 and elsewhere.

2. Incentive training resembles natural selection as follows. (a) For purposes of pursuing the analogy, incentive categories can be designated as "positive" or "negative" depending on whether they increase or decrease performance (cf. T. IA-4.3). As was indicated in S. IA-4.3, it is essentially a matter of definition that incentive training results in learning for target responses--more specifically, for responses whose occurrence or nonoccurrence fulfills the pertinent incentive contingency and thereby, as discussed above, permits the relevant incentive to affect performance, i. e., to change performance from one occasion to the next (cf. S. IA-2.5). However, except as noted below under b, incentive training of such responses generally does not comparably affect other responses, as will be discussed in Ss. IB-2.1 and IB-6.2. Thus, incentive training (natural selection) tends to result in
learning (evolution) only for those responses (phenotypic traits) whose fulfillment of a positive or negative incentive contingency (survival value) permits a relevant incentive (environmental factor) to change performance (the incidence of survival) of those responses (inherited traits) from one occasion (generation) to the next. (b) Training of one response can result in learning of a similar or related response. In fact, such training for one response can thereby be used to bring about the initial behavioral variation that is necessary for additional learning of a related response. One such procedure, called shaping, consists of training successively closer approximations to the desired response until the ultimate target response occurs.

3. Darwinian adaptation is the end result of incentive training in respect that performance generally tends toward a steady-state or asymptotic level under steady-state training conditions (e.g., see S. IB-1.2).

IA-4.7. Incentive Learning and Homeostasis

The foregoing analogy implies that incentive learning is a short-range extrapolation of the more long-range biological evolutionary processes. Just as long-range evolutionary processes based on mutation have the flexibility to readjust homeostatic processes slowly, so do analogous shorter-range processes have the flexibility to readjust homeostatic processes more rapidly as the necessity to do so arises. Insofar as homeostasis depends on such shorter-range processes (cf. S. IB-10.4), the organism's capacity
for such processes would epitomize a system having evolutionary survival value. As Slobodkin (1968) notes:

Certainly the appropriate response to an environmental factor which normally fluctuates on a rapid short-term basis is a physiological one. That is, a genetic response to the diurnal fluctuation of light and darkness is for most organisms absurdly inappropriate. In fact, there is an intimate connection between mean generation time, the period of fluctuation of an environmental variable and whether or not a genetic response to that variable by the population is appropriate...[p. 159]. Thus, homeostatic ability itself is being optimized by the evolutionary process [p. 162].

The relatively long-range evolutionary processes based on mutation thus favor the organism's capacity for analogous shorter-range processes supporting homeostasis. Hence, evolution is more than self-sustaining; it is self-amplifying. For example, natural selection among species has tended to favor species for whom diploid systems provide nondegenerative variation within the species and hence facilitate evolution of the species. Analogously, natural selection within certain species has tended to favor individuals who can learn, or evolve in terms of performance. Incentive learning as a Darwinian process thus falls squarely within the theoretical framework of evolutionary biology.

It should be noted that the word "extinction" as defined earlier herein is not analogous in meaning to biological extinction. That is, extinction of a response does not necessarily imply nonoccurrence of the response and may, in fact, imply increased performance in cases where the acquisition incentive as such decreases performance relatively to performance for an appropriate con-
trol group with no incentive. This terminological discrepancy is unfortunate, but the earlier definition of extinction was given because this definition is useful and corresponds to customary and long-standing behavioristic usage.
Chapter 5

TRAINING: CUES AND FEEDBACK STIMULI

IA-5.1. Positive and Negative Cues

As was indicated in S. IA-2.5, an occasion for obtaining a performance measurement may begin with presentation of a stimulus. In some training procedures such a stimulus is presented contingently on programming of an incentive to appear or to disappear subsequently upon fulfillment of the relevant response requirement. In other words, this initial stimulus predicts that an incentive contingency will be fulfilled provided that the relevant response occurs or fails to occur as required.

Thus, each onset of the predictive stimulus initiates a procedure comparable to that for an experimental group for characterizing an incentive as described earlier in S. IA-4.2. For comparison purposes each onset of another stimulus initiates a procedure comparable to that for the corresponding control group. The predictive stimulus is called a positive cue if it affects performance by virtue of the predictive property just described, in which case the comparison stimulus is called a negative cue. In order to conclude that a positive cue effect occurs "by virtue of" this predictive property, an experiment showing such an effect must be designed to allow for or to rule out the possibility that performance to the positive cue differs from performance to the negative cue for any alternative reason. The nature of such designs will be discussed in the next two sections. Cues constitute one of the
stimulus categories that were listed in T. IA-3.3. By current convention positive and negative cues are designated respectively as "S+" (or "S+D") and "S-" (or "S-A") (e.g., cf. Campbell & Church, 1969, Appx. A).

An S+ as defined above may be designated more specifically as a (positive) delayed cue in that its presentation does not occur until the associated contingency becomes effective. A positive trace cue differs definitively in respect that it is presented and terminated before the associated contingency becomes effective. A third type of cue is one that is presented before the contingency becomes effective but may be terminated after the contingency goes into effect, as will be discussed in S. IB-4.3.

IA-5.2. Differentiation

Suppose that an S+ and an S- are presented on separate occasions to each individual in a treatment group or in more than one treatment groups, and that performance is measured while the contingency following S+ presentation is in effect, and that performance is comparably measured following S- presentation. In this case any within-groups performance difference between the S+ and the S- is called differentiation if it occurs by virtue of the definitive predictive property of the S+. Since the word "differentiation" has an additional though related meaning, which will be given in S. IA-6.2, differentiation as defined above may be designated cue differentiation if necessary to obviate ambiguity.

The definition of (cue) differentiation indicates that dif-
Differentiation could be characterized as such with any procedure similar in principle to the following paradigmatic procedure. For an experimental group two stimuli are designated to be characterized as $S^+$ and $S^-$ in terms of their definitive predictive properties as described in the preceding section. For a corresponding control group, on the other hand, presentation of each stimulus initiates a procedure identical to that initiated by the other stimulus. This procedure may be any of the following, the first of which may be regarded as standard: (a) the same procedure that $S^-$ initiates for the experimental group; (b) the same procedure that $S^+$ initiates for the experimental group; (c) an intermediate procedure such as a partial reinforcement procedure.

Let the symbols "$S_1^+$" and "$S_0^-$" designate the stimuli that serve respectively as $S^+$ and $S^-$ for the experimental group. For each group apparent differentiation can be evaluated as performance to $S_1^+$ minus performance to $S_0^-$. True differentiation can then be evaluated as apparent differentiation for the experimental group minus apparent differentiation for the control group. In other words, differentiation represents a Stimuli ($S_1^+$ vs. $S_0^-$) x Groups interaction within groups.

The occurrence of such an interaction establishes that the $S^+$ affects performance by virtue of its definitive predictive property, since effects unrelated to this property cancel out in computing this interaction. Therefore, from the definition of $S^+$'s, occurrence of such an interaction is an essential criterion for establishing definitely that an intended $S^+$ does indeed function as
such. In fact, the essential aspect of the procedure described above is that it is designed so that such an interaction may be detected if present.

A refinement of this procedure is for the two stimuli $S_1$ and $S_0$ to be balanced between the two groups. That is, $S_1$ initiates the same procedure for the first group as for the experimental group described above, and for the second group $S_0$ initiates the same procedure that $S_1$ initiates for the first group. Thus, $S_1$ serves as $S^+$ for the first group, and $S_0$ serves as $S^+$ for the second group. The other stimulus for each group serves as $S^-$. With such a balanced procedure a within-groups interaction determined as above is operationally synonymous with a within-groups main effect of $S^+$ vs. $S^-$. From the definitions of $S^+$ and $S^-$, such a main effect is comparable to the main effect between experimental and control groups in a procedure designed to determine whether a stimulus is an incentive. From the earlier discussion in §IA-4.2, an effect between two such groups is an incentive effect. Therefore a within-groups main effect of $S^+$ vs. $S^-$ is operationally synonymous with such an incentive effect except in being a within-groups effect. Hence, since cue differentiation by definition is any within-groups effect of $S^+$ as compared to $S^-$, cue differentiation is an incentive effect of one stimulus as well as a cue effect of other stimuli.

In practice, the unqualified word "differentiation" is sometimes used loosely to denote apparent differentiation as described above. In related fashion the word "cue" is sometimes used loose-
Such loose usage is justified only when there are reasonable ground for assuming that apparent differentiation or an apparent cue effect represents the effect of a cue as such.

**IA-5.3. Cue Effects Between Groups**

Suppose that a stimulus is to be characterized as an incentive with experimental and control groups as described earlier in S. IA-4.2, and that the occasions for measuring performance begin with presentation of another stimulus, which will be designated "S_A" for present discussion purposes. Stimuli such as S_A were mentioned, under Item 1 in S. IA-2.5, in relation to occasions for measuring performance. Given that there are no a priori procedural differences between the two groups as far as S_A is concerned, any reliable performance difference between the groups must represent an incentive effect of some stimulus other than S_A.

Suppose further that two additional groups in the same experiment are run with a procedure identical to that for the aforementioned control group except that the occasions for measuring performance begin with presentation of a stimulus "S_B" instead of S_A. Since the procedure for these two groups is identical, it follows a priori that performance cannot differ reliably between them. Therefore, if an incentive effect occurs between the first two groups, the incentive necessarily interacts with the stimuli S_A vs. S_B, operationally.

From the discussion in the preceding section, it should be apparent that such an interaction establishes S_A as a cue.
the procedure just described, such an interaction is established between groups, and only in this respect does this procedure differ from the paradigmatic procedure described in the preceding section, in which the interaction described was within groups. As far as the present procedure is concerned, the crucial point is that an incentive effect between the \( S_A \) groups automatically establishes \( S_A \) as an \( S^+ \) for the experimental \( S_A \) group.

Thus, in practice, without any \( S_B \) groups being run, a stimulus such as \( S_A \) can be designated as an \( S^+ \) for a group such as the aforesaid experimental \( S_A \) group even though no interaction between \( S_A \) and the associated incentive is actually demonstrated. Hence, an \( S^+ \) as such can be presented to a group without presenting any \( S^- \) to the same group. Thus, for example, in the hypothetical experiment that was described in S. IA-3.1, the start box of the runway served as an \( S^+ \) for the experimental group.

Note that the reasoning developed above was based on the stated assumption that there are no a priori procedural differences between the experimental and control \( S_A \) groups as far as \( S_A \) is concerned. Thus, this reasoning does not apply if there is such a difference, and there is such a difference for any stimulus whose termination is contingent on fulfillment of a response requirement for the experimental group but not for the control group. Such a stimulus is therefore not a cue but an incentive, a drive, or a forfeit if it affects performance, although such a stimulus could be accompanied by a cue. In S. IA-4.1 it was said that an occasion for measuring performance may begin with presentation of such a
stimulus, one whose disappearance is contingent on a response requirement. Thus, if an occasion for measuring performance begins with presentation of a stimulus in a training procedure, this fact alone does not establish the stimulus as a cue.

IA-5.4. Feedback Stimuli

Suppose that a given stimulus appears or disappears contingently on occurrence or nonoccurrence of a given response and thereby facilitates learning supported by another stimulus, an incentive, that also appears or disappears contingently on occurrence of this same response. Suppose in addition that the given stimulus is never presented or terminated in conjunction with the incentive. The given stimulus is then called a feedback stimulus.

Thus, whenever any individual occurrence of a target response results in appearance or disappearance of the stimulus serving as an incentive, the same occurrence of the response does not result in appearance or disappearance of the stimulus serving as a feedback stimulus. Conversely, whenever any individual occurrence of the target response results in appearance or disappearance of the feedback stimulus, the same occurrence of the response does not result in appearance or disappearance of the incentive. Likewise, whenever the target response has failed to occur according to criterion on any individual occasion, nonoccurrence of the response may result in appearance or disappearance of the incentive or of the feedback stimulus, but not of both on the same occasion. The definition of feedback stimulus suggests various ways in which a
stimulus could be characterized as a feedback stimulus. Among these are the following two operations, which do not exhaust the possibilities but should clarify the definition.

1. From S. IA-4.2 recall how experimental and control groups are used to demonstrate incentive learning. Suppose that an active avoidance procedure with two such groups is to be used to characterize a stimulus as a punishment. Note that an active avoidance procedure by definition implies that the punishment is presented contingently on nonoccurrence rather than occurrence of the target response. Now suppose that an additional stimulus is presented contingently on occurrence of this same response for both the experimental group and the control group but is not presented for additional experimental and control groups otherwise treated identically to their counterparts. Then, if active avoidance learning is greater between the groups with this stimulus than between the groups without it, the stimulus fulfills the criterion of a feedback stimulus. Note that such an effect is an interaction between the feedback stimulus and the punishment. Insofar as any main effect or simple main effect of the feedback stimulus occurs as well, the feedback stimulus fulfills the criterion of an incentive as well as that of a feedback stimulus.

2. Suppose that incentive learning for an experimental group is manifested as a performance increment relatively to performance of an appropriate control group for evaluating incentive learning. For example, incentive learning might thus be escape or active avoidance or learning supported by a reward that is presented con-
tingently on occurrence of the pertinent response. Now suppose that an additional stimulus becomes contingent on occurrence of the target response for the two groups during extinction training, i.e., when the incentive contingency is no longer in effect. Suppose also that this stimulus is not presented for additional experimental and control groups otherwise treated identically to their counterparts. This stimulus is then a feedback stimulus if learning carried into extinction training is greater between the groups with this stimulus than between the groups without it. This feedback effect thus resembles the feedback effect in the preceding example in respect that each effect is an interaction between the feedback stimulus and the corresponding incentive.

In general, the occurrence of such an interaction is a definitive criterion whereby a feedback stimulus may be identified as such. It should be noted that such an interaction might represent an artefact in the sense that the interaction would disappear if performance were transformed to a different (e.g., logarithmic) scale (cf. Anderson, 1961). To preclude such artefacts in cases like those illustrated above, a demonstratively ideal feedback stimulus should be a reward only between the experimental groups with the incentive contingency, or else the feedback stimulus should be a punishment only between the corresponding control groups. If both these conditions hold, so much the better.

Feedback stimuli constitute one of the stimulus categories that were listed in T. IA-3.3. The name "feedback stimulus" is based on the fact that any feedback stimulus bears a contingency
relationship to the response affected by the feedback stimulus. The feedback stimulus thus engages in feedback like that already described for incentives (cf. Ss. IA-3.1 and IA-4.2).
IA-6.1. **Unconditioned Stimuli**

Any conditioning paradigm has the following two definitive features, which demarcate conditioning paradigms from training paradigms (cf. S. IA-4.1).

1. Neither appearance nor disappearance of a given stimulus is systematically contingent on either occurrence or nonoccurrence of a given response.

2. The stimulus affects the amplitude of this response systematically in association with the stimulus's appearance or disappearance.

"Appearance" of such a stimulus can be explicitly "systematic" only in reference to a control treatment whereby the stimulus fails to appear. Likewise, "disappearance" of a stimulus can be explicitly systematic only in reference to a control treatment whereby the stimulus fails to disappear. The stimulus in the foregoing definition is called an unconditioned stimulus (US or UCS). US's were among the stimulus categories listed in T. IA-3.3.

By current convention the words "conditioning" and "training" are not used interchangeably (e.g., Campbell & Church, 1969, Appx. A). However, training has been and occasionally still is called conditioning. Therefore, in contradistinction to training, conditioning is sometimes called classical conditioning or Pavlovian conditioning after Pavlov, who first investigated conditioning
(cf. S. IB-6.1 and Ch. 7, Part IB).

The foregoing definition of US's indicated that a stimulus may be characterized as a US with a procedure analogous to that described earlier in S. IA-4.2 for incentives. The essential difference is that with an experimental (as opposed to control) procedure a US appears or disappears in the absence of any systematic contingency related to the response under consideration. The corresponding control procedure is the same as if the stimulus were to be characterized as an incentive: The stimulus does not appear or disappear as it does with the experimental procedure. The analogy extends readily to drives and forfeits (cf. S. IA-4.4). Control procedures for characterizing US's can be dispensed with if they would be trivial (cf. S. IA-4.2).

Recall from S. IA-4.4 that training paradigms can be classified into twelve logically possible categories based partly on the response requirement—occurrence vs. nonoccurrence. This factor is irrelevant to any classification of possible conditioning paradigms, as the definition of conditioning would indicate. Without this factor the number of training categories would reduce to six. Therefore, insofar as US presentation or termination is considered analogous to stimulus presentation or termination upon fulfillment of a training contingency, conditioning paradigms might be thought to fall into six logically possible categories each demarcated from an analogous category of training paradigms.

However, conditioning paradigms actually fall into four rather than six logically possible categories because a US as a reward
analogue is identical to a US as a drive analogue, and a US as a
punishment analogue is identical to a US as a forfeit analogue.
For example, a US as either a reward analogue or a drive analogue
would not be present for a control group and would be presented
and later terminated for an experimental group regardless of
whether the pertinent response occurs (cf. Ss. IA-4.2 through
IA-4.4). Furthermore, if, say, occurrence of a response is re-
quired, a drive by definition increases response amplitude as does
a reward by definition.

Of the four categories of conditioning paradigms, two involve
US presentation, and two involve US termination. Apparently, in
practice, only US presentation has been investigated to any sig-
nificant extent. Therefore only US presentation will be referred
to from here on, but much of what applies to US presentation might
extend to US termination.

IA-6.2. Conditioned Stimuli

In conditioning paradigms a stimulus may be presented con-
tingently on programming of a US to appear subsequently. This ini-
tial stimulus thus predicts that the US will appear. Each onset of
this predictive stimulus therefore initiates a procedure equiva-
lent to that for an experimental group to characterize a US. For
purposes of comparison, each onset of a different stimulus may in-
itize a procedure equivalent to that for a control group of the
kind indicated in the preceding section.

The predictive stimulus is called a positive conditioned
stimulus if it affects response amplitude by virtue of the predictive property indicated, and the comparison stimulus is then called a negative conditioned stimulus. Conditioned stimuli in conditioning are analogous to cues in training in that conditioned stimuli and cues are both signals. Thus, to determine whether a positive conditioned stimulus affects response amplitude "by virtue of" its definitive predictive property, the effects of conditioned stimuli can be assessed with experimental designs analogous to those that were described for cues in Ss. IA-5.2 and IA-5.3. A positive or negative conditioned stimulus is conventionally designated "CS+" or "CS-" respectively (e.g., Campbell & Church, 1969, Appx. A). CS's were listed among the stimulus categories in T. IA-3.3.

As was indicated in S. IA-5.1, the definitive feature of any trace S+ is that it disappears before the associated incentive can appear or disappear through fulfillment of the associated response requirement. Analogously, a trace CS+ is defined as a CS+ that disappears before appearance of the associated US. In contrast, a delayed CS+ is defined as a CS+ that disappears as or after the associated US appears.

If response amplitude to a CS+ differs from response amplitude to a CS- within groups, the difference in response amplitude is called differentiation if it occurs by virtue of the definitive predictive property of the CS+. CS differentiation is thus the conditioning analogue of cue differentiation in training. Just as an S+ per sé may be presented to a group without presenting any S-
to the same group, for reasons that were discussed in S. IA-5.3, so may a CS+ per se be presented to a group without presenting a CS- to the same group, for analogous reason.

By reasoning that was set forth in S. IA-5.2, any cue effect is also an incentive effect insofar as an S+ effect evaluated relatively to an S- control treatment is identical to an incentive effect evaluated relatively to an appropriate control treatment. By analogous reasoning any CS effect is also a US effect insofar as a CS+ effect evaluated relatively to a CS- control treatment is identical to a US effect evaluated with the experimental and control treatments prescribed in the preceding section. However, it is possible alternatively to evaluate CS+ effects in such a way that they do not coincide with US effects. This is done by equalizing US presentation between CS+ and CS- treatments and by maintaining the definitive predictive property of the CS+, while not maintaining any such predictive property for the CS-. In this connection either of the following control procedures is applicable in relation to an experimental treatment whereby the CS+ retains its definitive predictive property.

1. The CS- and the US in the control treatment are presented in completely random temporal relation to one another while each being presented the same number of times as are the CS+ and the US in the experimental treatment (Rescorla, 1967b).

2. The CS- and the US are related through a contingency that is the reverse of the contingency between the US and the CS+ in the experimental treatment. Thus, CS presentation and US presenta-
tion are temporally juxtaposed in opposite directions between experimental and control treatments.

The foregoing control treatments as such have an inherent shortcoming: A CS+ effect evaluated relatively to one such treatment is constitutively different from a CS+ effect evaluated relatively to the other or to the standard control treatment of not presenting a US. Without sacrificing the standard operational meaning of a CS+ effect, it is still possible to evaluate CS+ effects, as such, independently of US effects. For example, suppose that a single stimulus serves as CS+ and CS- respectively for experimental and control groups receiving the treatments indicated in the preceding section, and that the procedure for two additional groups differs only in respect that the CS is not presented. Thus, the stimulus sequence for the four groups can be schematized as follows, where "O" designates nonpresentation of the CS or US: CS (as CS+) to US, CS (as CS-) to O, O to US, and O to O. Assuming that response amplitude is measured comparably among the groups, this $2^2$ design as such can distinguish among three mutually orthogonal (independent) effects: a CS (vs. no CS) effect, a US (vs. no US) effect, and a CS x US interaction tantamount to a CS+ vs. CS- effect between groups. Just as this design derives from the $2^1$ experimental-control design, so may a $2^3$ design be analogously derived from the $2^2$ design for demonstration differentiation—i.e., a within-groups effect of CS+ vs. CS- (cf. S. IA-5.2). CS differentiation, like the aforesaid between-groups effects, can thus be assessed orthogonally to US effects per se.
IA-6.3. **Conditioned Responses and Anticipation**

A CS+ effect as such must occur by virtue of the definitive predictive property of the CS+, as has been indicated. That is, such an effect must reflect the difference between the predictive properties of the CS+ and of the control CS−. Such an effect must thus be due to prior fulfillment of these properties insofar as the ongoing presence or absence of the associated US is uniform between the CS+ and CS− treatments. From the definition of learning, such an effect constitutes learning, as is likewise the case for S+ effects. In conditioning, any response for which such learning occurs is called a **conditioned response** (CR).

The response requirement of a given training procedure indicates what response is designated as the trained response with that procedure. However, conditioning procedures do not have response requirements, according to the definition of conditioning. Thus, an indefinite number of responses might be designated as CR's with any given conditioning procedure.

In one type of conditioning paradigm, CR's are specified in reference to "unconditioned responses." An **unconditioned response** (UR or UCR) is any response that a US elicits. If a UR consistently follows appearance of a US and therefore of a CS+, the CS+ will often come to elicit this same response before appearance of the US, as will be discussed in Chs. 6 and 7, Part IB. The response thus elicited by a CS+ is a CR by definition.

Such a CR is often called an **anticipatory response** to distinguish it from other types of CR's that will be indicated in 3.
IA-6.8. Insofar as a CS+ comes to elicit an anticipatory response because of conditioning, elicitation of this response is called anticipation. Pavlov first investigated anticipatory responses (cf. S. IB-6.1 and Ch. 7, Part IB), and the words "conditioned" and "unconditioned" arose through what amounts to mistranslation of the words "conditional" and "unconditional" from Pavlov's Russian into English. Pavlov used the words "conditional" and "unconditional" in the sense that elicitation of an anticipatory CR is conditional on experimental procedure, whereas elicitation of a UR is not.

Anticipation cannot occur for any UR. For example, although a US consisting of food may elicit eating, a CS+ signalling food cannot elicit eating if no food is present. To emphasize that anticipation does not occur for all behavior elicited by a US, an anticipatory response is sometimes called a fractional anticipatory response. Since US presentation is not contingent on occurrence or nonoccurrence of any anticipatory response, there is no purpose in defining occurrence of anticipatory responses as such. Hence, since performance of a response is defined in terms of occurrence of the response, the magnitude of any anticipatory response is designated more appropriately by the term "response amplitude" than by the less inclusive term "performance." Whereas "anticipation" refers, in essence, to an increase in the amplitude of a CR, the complementary term compensatory anticipation might be used to refer to the opposite effect, a decrease.
IA-6.4. Habituation Stimuli

A habituation conditioning paradigm is a conditioning paradigm in which the CS+ and the US are the same stimulus. In other words, this stimulus, called a habituatory stimulus, is a CS+ that signals its own presentation later as a US. Habituation conditioning and habituatory stimuli get their names from the fact that they are frequently investigated in relation to a type of learning called "habituation," which will be defined in the next section. However, the names still apply regardless of whether learning in a habituation conditioning paradigm takes the form of habituation. Habituation stimuli constitute one of the stimulus categories that were listed in T. IA-3.3.

The earlier discussion in S. IA-6.2 would indicate that conditioning involves successive stimulus presentations paired sequentially as CS+ and US. Although such sequential pairing has an objective basis when the CS+ and the US are separate stimuli, it would be arbitrary to present a habituatory stimulus only twice per sequence in habituation conditioning. Thus, habituation conditioning ordinarily involves more than two stimulus presentations per sequence, and the parametric number of sequences may range from one to any number of consecutive sequences that are reciprocally separated by time intervals exceeding the intervals between consecutive stimulus presentations within sequences.

Suppose that every other stimulus presentation be regarded arbitrarily as a CS+ presentation, and that the remaining stimulus presentations be regarded as US presentations, for an experimental
group in habituation conditioning. In this case, since the standard control procedure in conditioning consists of CS presentation without US presentation, as was indicated in S. IA-6.2, the frequency of stimulus presentations would be twice as great for such an experimental group as for a corresponding control group. Instead of using such experimental and control groups, a broader and more sensible approach, and the approach followed in practice, is to regard frequency of stimulus presentation as a continuum and as only one of various relevant parameters. Some results to be discussed in S. IB-8.3 indicate that habituatory stimuli may be presented at irregular intervals, and still the behavioral outcome is essentially the same as with regular stimulus presentations. The term "habituation conditioning" can thus apply to irregularly timed as well as regularly timed presentations of a habituatory stimulus.

In incentive training, as was discussed in S. IA-5.1, the procedure for a control group may involve repeated S- presentations unaccompanied by incentive presentation or termination. Likewise, in conditioning, the procedure for a control group may involve repeated CS- presentations unaccompanied by appearance of a US. Such control treatments in training and conditioning are operationally equivalent to habituation conditioning. Thus, in terms of habituation conditioning, such control treatments could be considered in their own right rather than only as reference points whereby to evaluate S+ and CS+ effects.
I.A-6.5. Habituation, Sensitization, and Fatigue

If habituation conditioning diminishes the magnitude of a stimulus-response effect involving the habituatory stimulus, the decrement is called adaptation. Adaptation in this sense should not be confused with Darwinian adaptation of the sort discussed previously in S. IA-4.6. Suppose that adaptation as defined above is evaluated parametrically for a stimulus-response effect along some dimension of the stimulus. If the parametric degree of adaptation is thereby related inversely to the parametric magnitude of this stimulus-response effect without prior habituation conditioning, adaptation is called habituation. Thus, as habituation conditioning progresses, there is a progressive exaggeration of an inverse parametric relationship between habituation and the ongoing magnitude of the stimulus-response effect. In other words, if initial parametric differences in a stimulus-response effect "fan out" as habituation conditioning progresses, this "fanning out" is called habituation insofar as it reflects adaptation.

A habituatory stimulus to which an intensity dimension is applicable can, of course, have a given behavioral effect only if the intensity of the stimulus is greater than zero. Thus, as a rule of thumb, the intensity of a stimulus is directly related to the parametric magnitude of any stimulus-response effect involving the stimulus. Therefore, since habituation by definition is inversely related to the parametric magnitude of a stimulus-response effect, habituation is inversely related to parametric stimulus intensity as a rule of thumb.
In other words, habituation is likely to occur to a greater degree at lesser stimulus intensities. More generally, habituation of a stimulus-response effect occurs to a greater degree as the stimulus-response effect diminishes parametrically along some dimension of the stimulus, as indicated above. However, this inverse parametric relationship reaches a limit where the lower limit (e.g., zero) of the stimulus-response effect constrains adaptation of this effect from being greater than if the stimulus-response effect were parametrically greater. Under these limiting conditions the inverse relationship still holds if habituation is evaluated as described later in S. IB-8.3, rather than being evaluated as adaptation.

Considering that habituation of a stimulus-response effect occurs to a lesser degree as the stimulus-response effect increases parametrically along some dimension of the stimulus, no habituation may occur at all when some point along this dimension is reached, and beyond this point habituation conditioning with the stimulus may actually enhance the magnitude of the stimulus-response effect. Such enhancement is called sensitization. Since habituation and sensitization are the end result of habituation conditioning, i.e., of prior presentations of a habituatory stimulus, habituation and sensitization represent learning by the definition of learning.

A habituatory response is a response that a habituatory stimulus elicits. Thus, insofar as a habituatory stimulus is a US as indicated in the preceding section, a habituatory response is a UR
for which anticipation or compensatory anticipation might be expected to occur as described earlier in S. IA-6.3. Anticipation of a habituatory response would constitute positive feedback in that the habituatory UR, being also the anticipatory response, would grow in amplitude if anticipation occurred. Such feedback would be manifested as sensitization. Conversely, compensatory anticipation would be manifested as habituation.

Suppose that adaptation of a habituatory response is evaluated parametrically along some dimension of the habituatory stimulus and turns out to be directly related to the parametric magnitude of the habituatory response as evaluated prior to adaptation. Such a direct relationship is antipodal to the inverse relationship defining habituation. Adaptation conforming to such a direct relationship is called fatigue.

IA-6.6. Adaptation and Habituation of Incentive Learning

The foregoing definitions of adaptation, fatigue, and sensitization do not restrict these processes to the effects of habituatory stimuli on habituatory responses. For example, suppose that incentive learning with a given incentive is less if the incentive previously served as a habituatory stimulus than if it did not. Such a decrement in an incentive effect fulfills the definition of adaptation. Suppose that such an adaptation effect is shown to have an inverse parametric relationship to incentive learning without prior habituation conditioning when incentive learning with vs. without prior habituation conditioning is parametrically
compared at various points along some dimension of the incentive. Adaptation would then fulfill the criterion of habituation.

To consider an example, adaptation of passive avoidance could be demonstrated with the following paradigmatic procedure. In Ph. 1 an experimental group would be given habituation conditioning with the stimulus to be used as a punishment in Ph. 2. That is, this stimulus would be repeatedly presented to the animals in this group without presentation or termination of this stimulus being response-contingent. The procedure would differ for the control group in respect that this stimulus would not be presented to the animals in this group in Ph. 1.

In Ph. 2 the procedure would be identical between the groups: Presentation of the punishment would be contingent on occurrence of a target response, and the punishment when presented would be at the same magnitude as it was for the experimental group in Ph. 1. Then, if punishment in Ph. 2 suppressed performance for the control group more than for the experimental group, adaptation to the punishment would be in evidence for the experimental group.

Such adaptation could be characterized definitively as habituation as follows. More than one experimental group would be run, and the procedure for each experimental group would be as described above. The procedures would differ among the experimental groups in respect that punishment magnitude would differ among them, although within each such group punishment magnitude would be the same in Ph. 2 as in Ph. 1.

For each experimental group a corresponding control group
would be run. The procedural difference between each experimental group and its control group would be as described above. Thus, the only procedural difference among the control groups would be that punishment magnitude in Ph. 2 would differ among them.

With this procedure adaptation could be evaluated between each experimental group and its control group. The parametric degree of adaptation could then be compared among these pairs of groups. If the degree of adaptation were thus found to be inversely related to punishment learning for the respective control groups in Ph. 2, the observed adaptation would fulfill the criterion of habituation.

IA-6.7. US's in Relation to Incentives

The definitions of conditioning and of US's notwithstanding, appearance of a US may be systematically contingent on fulfillment of a response requirement as long as the contingency is outside the frame of reference for conditioning. For example:

1. A stimulus may appear in the role of a US following CS+ presentation and yet may additionally appear in the role of an incentive, and thus appear contingently on fulfillment of a response requirement, following S+ presentation.

2. An incentive may appear contingently on fulfillment of a requirement concerning one response and yet may be conceived as a US for other responses to which the contingency does not apply.

3. In experimental paradigms as those considered in the next section, appearances of a CS+ and of a CS- may be contingent on a
requirement concerning a given response for, say, respective groups. A "US" accompanying the CS+ would then be systematically contingent on fulfillment of the response requirement (cf. S. IA-4.1) and thus would not be a true US, definitively, with reference to its own effect on that response. However, a CS+ vs. CS- effect on that response could be assessed orthogonally to the US effect, and thus to the response-US contingency, with an appropriate experimental design. Applicable designs were discussed in S. IA-6.2, and the principle of these designs extends readily to a variety of additional designs that will be encountered in Part IB. In the present example, insofar as the US-response contingency is irrelevant (orthogonal) to assessment of the CS+ vs. CS- effect, the US is tantamount to a true US as far as this effect is concerned.

The word "reinforcement" was defined in S. IA-4.3 but has some additional meanings besides that already stated. At this point the various definitions of the word will be given for the sake of completeness and because the general familiarity of this word may thereby help the reader to relate to some associated ideas already discussed. The definitions are as follows.

1. As was indicated in S. IA-4.3, the word "reinforcement" denotes appearance of a reward. This denotation could be extended to include disappearance of a drive-incentive.

2. "Reinforcement" means appearance of a US.

3. "Reinforcement" sometimes means reward, but to avoid confusion with the first meaning given above, the word "reinforcer"
is often preferred to the word "reinforcement" when referring to a reward.

4. The terms "reinforcement" and "reinforcer" may refer to a US.

The word "reinforcement" will rarely be used herein because its conventional meaning is too inexact and because the word anyway would not be a useful addition to the terminology already presented.

IA-6.8. Conditioned Incentives

Anticipatory responses and the like are not the only types of CR's. For example, as discussed throughout much of Part IB, a CS+ may change in its effectiveness as an incentive as a result of conditioning. In such a case, when a response is trained with a CS+ or a former CS+ as an incentive, this response is a CR as well as a trained response.

Such a stimulus is called a conditioned reward if conditioning results in this stimulus becoming more effective as a reward or less effective as a punishment. Analogously, a stimulus is called a conditioned punishment if conditioning results in this stimulus becoming less effective as a reward or more effective as a punishment. These definitions extend analogously to conditioned drive-incentives, conditioned forfeit-incentives, conditioned drives, and conditioned forfeits. If a US gives rise to a conditioned reward, a conditioned forfeit-incentive, or a conditioned forfeit, the US is called an unconditioned reward. Conversely, the
US is called an unconditioned punishment if associated with a conditioned punishment, a conditioned drive-incentive, or a conditioned drive.

As indicated in the preceding section, a CS+ may signal a US that is also an incentive. However, unconditioned incentives (unconditioned rewards and unconditioned punishments) as such are definitively US's as opposed to incentives. Part IB will be concerned with experiments in which a US is a true incentive, as well as other experiments in which a US is an unconditioned incentive as opposed to a true incentive.

If a CS+ signalling a punishment or an unconditioned punishment thereby affects performance of a trained response, which is then a CR as well, the associated increment or decrement in performance is commonly called fear. For US's that are rewards or unconditioned rewards, the analogous term hope might be used, although this term is used infrequently in the behavioral sense. Given that conditioning may change the effectiveness of a CS+ as an incentive as has been described, the following logically symmetrical possibilities should be noted.

1. Conditioning may alter the effectiveness of a CS+ as a US in second order conditioning, as discussed later in S. IB-6.1.

2. Training might alter the effectiveness of an S+ as an incentive (cf. S. IB-11.4).

3. Training might alter the effectiveness of an S+ as a US (cf. S. IB-6.3).
Part I

STIMULUS CONTROL OF BEHAVIOR

B. AN EMPIRICAL ANALYSIS
Chapter 1

REWARDS, PUNISHMENTS, AND DRIVES

IB-1.1. Behavioral Effects and Stimulus Categories

This chapter and the remaining chapters in Part IB are concerned with describing, interpreting, and integrating some diverse behavioral effects in terms of general principles of stimulus control. An underlying principle integrating all others is that learning is a Darwinian process as described earlier in S. IA-4.6. The introductory discussion in that section will be extended at various points in succeeding chapters.

In Part IB the unifying framework for discussion will be the stimulus categorization scheme that was presented in T. IA-3.3. This scheme provides a foundation for interpreting some rather complex behavioral effects that will be described in later chapters. Before building on this foundation, it is appropriate first to secure the foundation itself, i.e., to corroborate this scheme in terms of empirical findings, not only for the purpose of illustrating the meanings of the various categories in the scheme, but also because the validity of the scheme depends on such corroboration for reasons that were noted in S. IA-3.4.

The first main stimulus categories to be considered will be those of incentives and of drives and forfeits. In this chapter the subcategories, e.g., rewards, within these categories will each be discussed separately. The primary emphasis in this chapter will be on rewards, punishments, and drives, because the pertinent
research has mostly been concentrated on such stimuli. In the next chapter incentives will be discussed in terms of their more general aspects.

IB-1.2. Rewards

The definition of "reward" was given in T. IA-4.3 and may be restated in syntactic form, without any change of meaning, as follows: A stimulus is a reward if it has appeared contingently on occurrence or nonoccurrence of a given response, and if performance of the response respectively increases or decreases as a result. In one experiment, for example, when bar pressing by rats yielded 20% sucrose solution, bar pressing rate increased more than for a control group for whom bar pressing yielded water (Smith & Kinney, 1956). Sucrose therefore fulfilled the criterion of a reward in this experiment.

Perhaps the most commonly used experimental rewards are solid food given to hungry animals and water given to thirsty animals (cf. Pubols, 1960). Other demonstrated rewards include, for example, administration of various drugs (e. g., see Schuster & Thompson, 1969) and electrical stimulation of the brain (e. g., see Trowill, Panksepp, & Gandelman, 1969). Many additional types of rewards will be mentioned in relation to various topics to be discussed.

As was indicated in S. IA-4.3, reward learning can be evaluated as a function of reward magnitude. This has been done for rats in various experiments in which the rewarded response was en-
try into a runway goal box baited with the reward. In this para-
digm performance is measured as the speed with which rats enter
the goal box after being placed in the start box of the apparatus.
In one experiment, as an example, when rats received sucrose solu-
tion upon entry of a runway goal box, performance increased para-
metrically with sucrose concentration (Young & Shuford, 1955). Re-
ward learning was thus a monotonic function of reward magnitude,
specifically sucrose concentration. In some other experiments, to
illustrate further, reward learning resulted from training with
light as a reward, and the degree of reward learning was found to
be directly related to the intensity of the light (Forgays & Lev-
in, 1957; Premack, Collier, & Roberts, 1957).

Trained performance often approaches an asymptote, a steady-
state level, as the cumulative number of trials or training occa-
sions increases. With the runway procedure, if learning rate is
measured as per-trial performance increase divided by asymptotic
performance, learning rate on any given trial does not differ sub-
stantially among groups of rats that are given respectively dif-
ferent magnitudes (weights) of solid food reward for entering the
goal box (see Pubols, 1960). At the same time, however, there is a
primarily direct relationship between parametric reward learning
and the parametric weight of solid food reward, where the weight
of the food provided corresponds directly with the time spent eat-
ing and the weight of the food eaten. Thus, parametric reward
learning and learning rate, measured as described above, are not
necessarily related to each other.
In the various examples considered above, reward was presented contingently on occurrence of some response. The following experiment provides an example of reward presented contingently on failure of a response to occur (cf. the above definition of reward). In this experiment thirsty dogs in one group were given water for salivating (Miller & Carmona, 1967). For another group of dogs, also thirsty, water was given whenever a dog would produce no saliva (zero drops) during a set time interval. Water was shown to be a reward under the conditions of the experiment in that salivation increased for the dogs given water for salivating, whereas salivation decreased for the dogs given water for not salivating. However, the experiment did not demonstrate whether water was a reward for both groups as opposed to being a reward for only one group, since a control group was not tested to assess the possibility that salivation might increase or decrease with no water reward and with other things equal.

IB-1.3. Punishments and Drive-incentives

The definition of "punishment" was presented in T. IA-4.3 and may be restated syntactically as follows: A stimulus is a punishment if it has appeared contingently on occurrence or nonoccurrence of a given response, and if performance of the response respectively decreases or increases as a result. In an illustrative experiment a toy snake was presented to monkeys just as they reached for food (Masserman & Pechtel, 1953). Subsequently, the monkeys avoided reaching for food, even to the point of starva-
tion. The toy snake thus fulfilled the criterion of a punishment, and suppression of the "reaching for food" response constituted passive avoidance.

Electric shock administered through a grid floor is perhaps the most commonly used experimental punishment for murids. A typical passive avoidance paradigm involves shocking rats for lever pressing for food reward after the rewarded lever pressing response has been learned and while it is still being rewarded. In this paradigm lever pressing rate decreases with a parametric increase in shock duration (Estes, 1944; Church, Raymond, & Beaucamp, 1967) or intensity (Dinsmoor, 1952; Estes, 1944; Church, 1969).

In experiments based on another passive avoidance paradigm, rats first learned to run down a runway to obtain food (Karsh, 1962, 1963). Subsequently, the procedure was changed in respect that the rats were shocked when they picked up the food. A parametric increase in voltage resulted in relatively greater suppression of response speed. For a given parametric intensity and duration of shock, performance increases when a parametrically increased weight of food reward is contingent on the shocked response (e.g., Church & Raymond, 1967; see Church, 1963). For various responses active avoidance of shock increases with the parametric duration and intensity of the shock (e.g., see Reiss, 1970).

The term "drive-incentive" was defined in T. IA-4.3. To restate the definition in syntactic form without any change in mean-
ing, a stimulus is a drive-incentive if either of the following conditions holds.

1. Performance of a given response increases in the presence of the stimulus because occurrence of the response has previously terminated the stimulus.

2. Performance of a given response decreases in the presence of the stimulus because nonoccurrence of the response has previously resulted in termination of the stimulus.

To take an example, in one experiment a wheel-turning response by rats could terminate a low intensity buzzer for 15 sec. for an experimental group but not for a control group for whom the buzzer sounded continuously throughout the training period (Myers, 1965). Turning the wheel during the 15-sec. termination period had no effect on the buzzer. For both groups response rate was calculated for those responses having interresponse intervals exceeding 15 sec., so that only those responses occurring while the buzzer sounded were counted for the experimental group. Response rate for wheel turning was found to be higher for the experimental group than for the control group. Thus, the buzzer fulfilled the criterion of a drive-incentive, and, for the experimental group, enhancement of response rate constituted escape from the buzzer.

IB-1.4. Drives

Drives have been investigated considerably more than drive-incentives. Among the most commonly investigated drives are deprivation stimuli. To consider an example, in one experiment licking
of a calcium lactate solution was greater in rate for a group of calcium-deprived parathyroidectomized rats than for a control group of parathyroidectomized rats that were not deprived of calcium (Lewis, 1964). Calcium deprivation was thus shown to be a drive.

In other experiments rats maintained on protein-free diets were shown to prefer casein to sugar, whereas nondeprived rats preferred sugar to casein (Young, 1941, 1948). Protein deprivation was therefore a drive under the experimental conditions. In a different experiment thiamin deprivation was shown to be a drive in that thiamin-deprived rats preferred food with thiamin to the same food except without thiamin, whereas nondeprived rats did not show this preference with an identical training procedure (Rozin, Wells, & Mayer, 1964). Similarly, histidine-deprived rats in another experiment were shown to select a histidine solution (Rogers & Harper, 1970).

In general, rats select a remarkable well-balanced diet (Richter, 1943). To complete the picture, an experiment should be noted in which thirsty rats with a volume deficit were shown to prefer saline to water, whereas thirsty rats with an osmotic deficit preferred water to saline (Smith & Stricker, 1969). Volemic and osmotic thirst were thus shown to be reciprocally distinguishable drives. In contrast, another experiment showed that separate groups of thiamin- and pyridoxine-deficient rats did not differ from each other in their preferences between thiamin and pyridoxine (Rodgers, 1967).
Perhaps the most commonly investigated deprivation drive is hunger induced by not allowing animals to eat any food at all during the period of deprivation. The effects of hunger drive have been investigated in a number of experiments in which rats have been given food reward contingently on occurrence of a target response. In such experiments the rats are typically given less food than they would eat if more were available. Such a procedure allows hunger drive to be investigated without being confounded with the amount of food eaten, except at such low drive magnitudes that the rats refuse the food. A typical result of such investigations is that a parametric increase in hunger drive causes a corresponding increase in motivation (e.g., see Black, 1965).

Some such investigations have been concerned with the issue of whether or how hunger drive affects learning measured as a parametric function of weight of food reward. In a typical experiment investigating the issue, performance is measured as runway response speed for rats. Hunger magnitude is lower for G. 10 than for G. 20, and G. 01 is given less food than is G. 02.

From comparisons among such experiments, it seems that intermediate magnitudes of hunger and food weight do not interact, but that a negative interaction occurs with great hunger and large weights of food for the four subgroups, and a positive interaction occurs with no hunger and no food reward for Gs. 10 and 01 respectively (see Black, 1965). This positive interaction is such that performance is essentially equal among Gs. 11, 12, and 21. Note that such an interaction would not disappear if performance were
transformed from the original scale to another scale of measurement.

Along with hunger electric shock administered through a grid floor is perhaps the most commonly used experimental drive. Escape from shock increases with parametric shock intensity for responses for which the relationship has been investigated (e.g., see Riess, 1970). Forfeits and forfeit-incentives remain largely uninvestigated (for examples, see Bruning, Kintz, & Mogret, 1965; Tolman & Mueller, 1964).
Chapter 2

INCENTIVES

IB-2.1. Darwinian Selectivity of Training

From S. IA-4.2 recall the type of procedure whereby performance is compared between experimental and control groups in order to determine whether a given stimulus is an incentive. With such a procedure or some related procedure by which incentive effects can be assessed, response amplitude can be compared between the groups not only for the response relevant to the incentive contingency but for other, irrelevant responses at the same time. By such comparisons, learning typically occurs only for the relevant response and not for irrelevant responses.

In other words, an incentive training procedure directed at a given response tends to affect that response selectively—selectively in the Darwinian sense. In S. IA-4.6 this point was briefly touched on in discussing an analogy between incentive learning and evolution. Some experiments illustrating the point will now be discussed.

In one experiment, after solely an increase or a decrease in urine formation was rewarded in rats, urine formation respectively increased or decreased, and heart rate and blood pressure changed relatively little (Miller & Dicara, 1968). Yet it has been shown repeatedly that heart rate in rats changes in the appropriate direction when solely an increase or a decrease in heart rate is rewarded (e.g., Miller & Banuazizi, 1968; Miller & Dicara, 1967;
Moreover, in one of the experiments, solely an increase or a decrease in intestinal contraction was rewarded in additional rats, and learning occurred in the appropriate direction (Miller & Banuazizi, 1968). Yet heart rate did not change during this procedure, and intestinal contractions were not altered in the rats that were rewarded for changes in heart rate. For both types of responses the same reward, electrical stimulation of the median forebrain bundle, was used. In a second phase of the experiment, reward was no longer given for the changes in intestinal contraction, and performance then reverted to its original level. This reversion is an example of extinction.

The foregoing examples of selective training effects illustrate what appears to be a general principle analogous to that of selectivity in natural selection, though the possibility of exceptions is granted. The important point is that as a general rule the crucial factor in incentive learning is not simply the presence of an incentive but is, rather, the incentive contingency perse in relation to the relevant response. The following experiment further illustrates the point.

In this experiment a dog would be shocked on a forepaw after it started to eat pellets (Lichtenstein, 1950). As a result, eating was inhibited; one of the dogs permanently refused to eat pellets unless they were ground into mash. Yet—and here is the essential point—the same experiment showed that shock given prior to eating did not likewise suppress eating, even though the shock was administered after food presentation. The shock contingency
rather than the shock per se was thus the factor that suppressed eating.

Given that the critical factor in learning is an incentive contingency in relation to some response, it might be expected that an almost limitless variety of responses could be trained provided that an appropriate incentive contingency be in effect. In fact, a remarkable variety of responses have been trained. To mention just a few, the galvanic skin response, measured by electrical skin conductivity or potential, has been reward-trained in humans (e.g., Birk et al., 1966; Crider, Shapiro, & Tursky, 1966; Fowler & Kimmel, 1962; Kimmel & Kimmel, 1963), and electromyographic responses in curarized dogs can be trained with reward and punishment (Black, 1967). Vasodilation has been trained as an escape response to shock in humans (Lisina, 1958); vasoconstriction is the normal response to shock. Electrical activity of the brain ("thinking"?) has been directly trained by means of reward and punishment (e.g., see Black, 1971). Male sexual behavior has been suppressed with mild punishment in rats (Beach et al., 1956) and dogs (Gantt, 1944).

A variety of additional responses have been trained in other experiments described in succeeding sections and chapters. In summary, as a general rule an incentive training procedure directed at a given response is likely to affect that response and to do so selectively. This principle is paramount to any interpretation of incentive learning as a Darwinian process, as the earlier discussion in S. IA-4.6 would indicate.
IB-2.2. **Incentive Equivalency Among Responses**

Typically, though not necessarily, if a stimulus appearing or disappearing contingently on one response is a particular type of incentive, e.g., a punishment, for that response, the same stimulus can serve as the same type of incentive for another response. For example, when passive avoidance was discussed in S. IB-1.3, it was mentioned that shock can serve as a punishment for both lever pressing and runway responses. To mention another example, in an experiment in which male rats could run to a female in either arm of a T-maze, both response speed and choice performance were higher for the side on which ejaculation rather than just intromission was permitted (Kagan, 1955). Different responses tend similarly to be equivalent in the case of drives. For example, for rats given response-contingent sodium chloride, choice performance in a T-maze and bar pressing rate were both enhanced with an increase in time since adrenalectomy in one experiment (M. Lewis, 1960).

In S. IB-1.2 quantitative incentive-response relationships were discussed for food reward in a runway. Similar relationships hold for choice performance. With a choice between food reward and no food reward in a T-maze, choice performance to the food arm increases faster for rats given a relatively greater amount of food reward (Hill, Cotton, & Clayton, 1962). A similar result was obtained for monkeys (Meyer, 1951). When rats are given a choice between large and small food rewards in a T-maze, choice performance toward the large reward increases more slowly when the size of the small reward is relatively great and therefore closer to the size
of the large reward (Hill & Spear, 1963).

In summary, it may be stated as a rule of thumb that a given stimulus is likely to have equivalent incentive properties among separate responses. However, this rule is far from inviolable. For example, if incentive presentation is contingent on a response that is virtually certain not to occur, the incentive obviously cannot affect that response, regardless of how other responses are affected (cf. S. IA-4.6). This seemingly truistic fact is sufficient to account for the remarkable finding that chimpanzees, who cannot learn to speak human language, can be taught the sign language of the deaf (cf. Gardner & Gardner, 1970). More mundanely, relationships between incentive learning and incentive magnitude may vary among responses because of floor and ceiling effects, or because random performance variation for one response obscures effects that would be observed for other responses, or because differences in performance scales distort the relationship between incentive learning and incentive magnitude among separate responses.

Such reasons might be applied to rationalize the results of the following experiment. In this experiment, which used a two-unit T-maze, several parametric weights of food reward were given (Furtchgott & Rubin, 1953). Learning rate was measured as the inverse of trials to criterion, and incentive learning was measured, as always, in terms of performance, which was measured as the inverse of precriterion errors. Performance as well as learning rate was less for a control group not given food than for the other
groups but was virtually the same among all the groups given food, even though the variation in food weight was within the range yielding the parametric differences in incentive learning that were discussed in S. IB-1.2 and above for runway and single-unit T-maze experiments.

Although such discrepancies could be dismissed with the above reasoning, it is not so easy to dismiss findings that incentive magnitude and the trained response interact in such a way that the parametric gradients of incentive learning are opposite in direction between responses. Such an interaction is illustrated in the following experiment. In this experiment sodium chloride solutions were used as rewards for rats that were neither hungry nor thirsty, and learning was investigated as a function of sodium chloride concentration in distilled water (Young, Falk, & Kappauf, 1958). Measured as response speed for running to obtain the solution, performance was highest for 2.7 g/cc sodium chloride, but rats had been shown to prefer .9 g/cc sodium chloride to other concentrations. The following experiments, while not explaining these findings, place them in an interesting perspective.

In one experiment rats not deprived of food or water had unlimited access to .8 g/cc sodium chloride in distilled water and drank so much of it that various organs were enlarged, growth was retarded, and other toxic effects appeared (Nelson, 1947). Schmidt (1964) allowed undeprived rats to have free access to .9 g/cc sodium chloride and observed that rats injected with phenobarbital
drink so much of the solution that they overload the stomach and gut and some of the solution flows out the anus. These rats seem literally unable to withdraw from the drinking tube [p. 204].

The salt concentrations used in these two experiments corresponded to the concentrations for which the rate of short-term consumption was found to be maximal in various rat experiments (see Schmidt, 1964; Weiner & Stellar, 1951; Young & Falk, 1956).

Not only may the gradients of incentive learning be opposite in direction between responses, as in the foregoing example, but a given stimulus may even have diametrically opposite incentive properties between responses with other things equal. An example will be encountered in S. IB-10.8. Thus, it is not uncommon for a stimulus to have opposite effects between separate experiments. For example, light has been shown to be both a reward (Kiernan, 1964; see also S. IB-1.2) and a punishment (Keller, 1941) (see also S. IB-2.5). Such opposing effects might represent interactions between magnitudes of different incentives, as will now be discussed.

IB-2.3. Interaction Between Magnitudes of Different Incentives

The following heuristic can account for the fact that incentive magnitude or simple an incentive vs. no incentive can interact with the response undergoing training. Suppose that an experimenter programs Stimulus A to appear or to disappear contingently on occurrence of Responses X and Y for respective groups of animals, while at the same time Stimulus B, without the experiment-
er's knowledge, appears or disappears contingently on occurrence of Response X but not of Response Y. Then, if the magnitudes of stimuli A and B interacted with each other in terms of incentive learning, the incentive effects of Stimulus A could thereby differ between Responses X and Y.

It is readily apparent that the magnitudes of different incentives may indeed interact with one another unequivocally—i.e., in such a way that the interaction would not disappear if performance were transformed from the original scale to another scale of measurement. For example, it has been suggested that a breeze may be a reward or a punishment depending on the ambient temperature (Church, 1969), which may also have incentive properties. The following experiment demonstrates an unequivocal interaction between the magnitudes of different incentives.

Rats in this experiment were given a choice between a sucrose solution and another solution of sucrose and quinine together (Kappauf, Burright, & DeMarco, 1963). The rats were neither hungry nor thirsty. The experiment consisted of several phases within which quinine concentration and sucrose concentration in the sucrose-alone solution remained constant.

Within any given phase sucrose concentration in the sucrose-quinine solution was varied among the individual rats. An "equilibrium" concentration producing no preference was thus determined for the rats as a group. Since it had already been established that rats prefer relatively more concentrated sucrose solutions to relatively less concentrated sucrose solutions, quinine preference
in any given phase was in effect considered to be sucrose concentration in the sucrose-alone solution minus the equilibrium sucrose concentration.

Quinine concentration and sucrose concentration in the sucrose-alone solution were the measures of incentive magnitude and were varied separately from each other among phases. The phase sequence was randomized for each rat individually. The factors of incentive magnitude were thereby separated, groupwise, from the factor of phase sequence and were thus parametric in nature. Quinine preference, evaluated in each phase, was determined as a function of the incentive magnitudes for quinine and sucrose.

At relatively low parametric sucrose concentrations, increasing quinine concentration up to a threshold did not affect quinine preference, but quinine preference decreased with further increases in quinine concentration. At higher parametric sucrose concentrations, quinine preference first increased and then decreased with increases in quinine concentration. The increase in quinine preference was relatively greater at relatively higher parametric concentrations of sucrose. In summary, low quinine concentrations were rewarding but only in combination with sufficiently high parametric concentrations of sucrose.

At these high concentrations, as quinine concentration increased beyond the optimally rewarding concentration, there was a "neutral" quinine concentration at which quinine preference was the same as at a zero concentration. Hence, at this neutral concentration quinine was neither rewarding nor punishing. Higher
quinine concentrations were punishing in that quinine preference was lower than at the neutral concentration. Still higher quinine concentrations appeared to be "infinitely" punishing in that the rats would not drink quinine at this concentration regardless of parametric sucrose concentration.

IB-2.4. Environmental Factors Affecting Incentive Learning

In preceding chapters and sections, various factors influencing incentive learning have been discussed. At this point it is apropos to summarize these factors along with some additional factors not yet discussed that affect incentive learning. The following effects are relevant in this regard.

1. As was discussed in S. IA-4.6, appropriate response variation must occur initially in order for incentive learning to take place. Factors affecting initial response variation will be discussed in S. IB-3.3 and elsewhere.

2. The magnitude of an incentive may affect learning with that incentive, as discussed in the preceding section and in the preceding chapter.

3. Certain incentives may have species-related effects on performance.

4. Drive magnitude may affect incentive learning, as discussed previously in S. IB-1.4.

5. Incentive learning may reflect an interaction between the response being trained and the occurrence or magnitude of the incentive in training, as was discussed in S. IB-2.2.
6. As discussed in the preceding section, the occurrence or magnitude of one incentive may affect learning with another incentive, and such effects might in some cases account for interaction between the response being trained and the occurrence or magnitude of the incentive in training.

7. As will be discussed in S. IB-3.4, incentive learning may depend on what cue accompanies the incentive, and this effect may occur above and beyond any cue effects on initial response variation. The general subject of cues will be discussed beginning in the next chapter.

8. There is ample evidence that incentive learning may be altered through learning previous to initiation of the ongoing training regimen, independently of any effects on initial variation of the target response. The evidence for such effects will be discussed at various points in Part IB starting in Ch. 8. In certain cases the existence of such effects explains why the occurrence or magnitude of one incentive might affect learning with another incentive, as will be discussed in S. IB-10.1.

9. In incentive-training experiments the incentive is presented or terminated at the end of a delay interval that begins either at the point in time when the required response occurs, or at the criterion point in time when the prohibited response has failed to occur for the required duration of time. This delay interval may be negligibly short and usually does not exceed a few seconds, but at any rate this interval is usually intended to be constant, for practical purposes, within an experiment. If, how-
ever, this delay interval is varied as a treatment parameter, it may affect incentive learning, as will be discussed in Ss. IB-12.1 and IB-12.2.

10. In addition to effects such as those already mentioned, miscellaneous effects can occur. For example, bar pressing rate for water decreases for rats previously allowed to lick an air stream (Hendry & Rasche, 1962).

IB-2.5. Appetitive and Aversive Stimuli

Incentives and drives have conventionally been categorized as "appetitive" and "aversive." The word aversive is applied to punishments, drives, and drive-incentives, and the word appetitive applies to the diametrically opposite categories of stimuli. However, just because electric shock, say, happens usually to act as a punishment as well as a drive (cf. Ss. IB-1.3 and IB-1.4), it does not follow that such congruence is the unexceptionable rule.

In one experiment, for instance, brain stimulation was applied at a single site in each of several rats and yet was found to serve as a drive in training escape by running, was found not to serve as a punishment in training avoidance by running, and was found to serve as a reward for bar pressing (Bower & Miller, 1958). The observed failure to avoid was not due to some peculiar inability of the rats to learn through previous punishment, since they did learn to avoid when the incentive consisted of brain stimulation along with electric shock to the skin. Apparently, then, the brain stimulation simply was rewarding and not punish-
ing, even though it acted as a drive.

In another experiment each of several rats was simultaneously trained to press one bar to turn on electrical stimulation to the brain and to press another bar to turn it off (Kirschner, reported in Miller, 1957). These rats continued repeatedly to press one bar after the other in alternation. Thus, brain stimulation in this experiment apparently acted as both a drive and a reward.

Such apparently opposing effects might be expected in view of some results to be discussed in Ss. IB-6.3 through IB-6.5. These results indicate that a stimulus presented contingently on a response can often be expected to produce incentive learning manifested as a performance increase if the stimulus after being presented elicits the same response. Thus, if a reward, say, elicits that response upon whose occurrence appearance of the reward was contingent, the reward may function as such for this reason largely. Yet because this stimulus elicits that response, the stimulus can function as a drive as well for the same response.

The results described above cast suspicion on the assumption that there is a worthwhile distinction to be made between appetitive and aversive stimuli as such. The results of some further experiments confirm this suspicion. In one experiment, for example, it was found that a change in a light stimulus was, per se, able to support learning of a bar pressing response (McCall, 1965).

In another experiment bar pressing by rats resulted in their being forced to run in a motor-driven running wheel (Hundt & Premack, 1963). The apparatus permitted the rats to drink while run-
ning, and, if the motor was turning the wheel, drinking turned off the motor. The wheel then remained immobile until reactivated by a bar press. Activation of the motor was found to serve as both a reward and a drive in that the contingencies of the experiment resulted in an increased lever pressing rate and in increased drinking.

Control data showed that running in the wheel did not, per se, result in increased drinking. Thus, the observed increase in drinking was due to the contingency between drinking and deactivation of the motor. Hence, activation of the motor was a drive-incentive as well as a drive and a reward. In summary, there is ample evidence that a stimulus functioning as a punishment, a drive, or a drive-incentive does not necessarily function as a punishment, a drive, and a drive-incentive.
IB-3.1. **Differentiation**

By definition, cue differentiation as such can occur only by virtue of the definitive predictive property of the $S+$ involved. In demonstrating differentiation the "by virtue of" condition can be satisfied with an experimental design that is balanced as described previously in IA-5.2. The following experiment illustrates the use of a balanced design and provides an illustration of differentiation.

Curarized rats were each presented with a flashing light, a tone, or neither at irregular intervals and in an irregular sequence (DiCara & Miller, 1968). For half the rats $S+$ was the flashing light, and $S-$ was the tone. For the other half $S+$ was the tone, and $S-$ was the flashing light.

Half the rats from each of these groups were in G. 1, and the remaining rats were in G. 2. The stimuli were thus balanced within G. 1 and within G. 2. Note that balancing provides control for possible differences in drive or forfeit effects of $S+$ and $S-$ when $S+$ and $S-$ are terminated contingently on occurrence of the required response, as is often the case, and as the case was in the present experiment.

Each rat in Gs. 1 and 2 was shocked if and only if its heart rate did not respectively increase or decrease to criterion within 5 sec. after $S+$ presentation. Whenever the rat's behavior would
meet the criterion within the 5 sec., cue presentation was immediately terminated. For G. 1 heart rate was higher when S+ was presented than when S- or a "blank" period occurred. Conversely, heart rate for G. 2 was lower when S+ was presented than when S- or a "blank" period occurred. These differences within each group indicate avoidance of the shock and provide an example of differentiation.

In this experiment performance to S+ differed increasingly betweenGs. 1 and 2 as the experiment progressed. However, although differentiation continued to increase at the same time, heart rate was still higher for G. 1 than for G. 2 following onset of S-. This performance difference to S- progressively increased and is an example of generalization in that the learning that occurred with S+ carried over to a stimulus other than S+. Although this other stimulus happened to be S-, the observed generalization would still have been generalization had it appeared following presentation of a new stimulus, one not previously serving as S-.

The above experiment illustrates training with a delayed cue in that S+ was not terminated before the required response occurred. A trace cue, on the other hand, would be terminated before the incentive contingency became effective, as was indicated in S. IA-5.1. The time interval may be quite long between S+ termination and actualization of the incentive contingency—24 hours, for example (Capaldi, 1967).

In an experiment that illustrates training with trace cues, dogs were trained in Ph. 1 to press a panel for food when the pan-
was illuminated (Ellison, 1963). In Ph. 2 a brief tone was presented 7.4 sec. before panel illumination. S+, a high-pitched tone, and S-, a low-pitched tone, were consistently paired respectively with availability and unavailability of food reward and controlled panel-pressing accordingly. Unfortunately, the results of this experiment only suggest differentiation to trace cues, since the trace cues were not reported to be balanced among individuals, but the experiment does illustrate simply the concept of trace-cue training, which will be fully discussed in the next chapter.

As was shown in S. IA-5.3, an S+ as such may be presented to a group in a training procedure without any S- being presented to this group during the procedure. An S+ effect may vary considerably depending on whether an S- is also presented. Solomon (1964) provides a common-sense example:

The suppression of urination in dogs, under the control of indoor stimuli [S+], is extremely effective in housebreaking the dog, as long as urination is allowed to go unpunished under the control of outdoor stimuli [S-] [p. 241; italics in original].

IB-3.2. Generalization

An S+ presented during a typical one-phase training procedure has essentially the same magnitude with each presentation. After such a training phase, if this stimulus is then presented at a different magnitude, generalization may often be observed. Generalization is usually less—i.e., performance usually shows a greater generalization decrement—with a greater magnitude difference between the original S+ and the altered cue presented subse-
quently. In other words, performance usually follows a descending generalization gradient as the S+ from initial training is further changed in magnitude along some dimension.

Generalization gradients in training have been observed along the following dimensions, for example: illumination intensity of a direct light source used as a cue in training rats to run for food reward (Brown, 1942); loudness of a buzzer used as a cue in training rats to avoid shock in a T-maze (Miller & Greene, 1954); decreasing albedo of a runway (Raben, 1949); and increasing or decreasing size of a white circle serving as a cue (Grice & Saltz, 1950). Among the many other experiments on generalization gradients, the stimulus magnitudes most commonly investigated with training procedures have perhaps been stimulus intensities or, more specifically, loudness of sound (e.g., cf. Fink & Patton, 1953) and illumination intensity of a direct light source (e.g., cf. Fink & Patton, 1953; Frick, 1948). Typically, as in the various experiments just referred to, generalization gradients descend monotonically. However, such is not always the case. For example, in a runway experiment in which only one of several pure frequency tones had reliably signalled availability of food reward for rats, the generalization gradient for response speed turned upward at a frequency one octave lower than this tone (Blackwell & Schlosberg, 1943). A possible example of an ascending generalization gradient will be mentioned in S. IIA-4.5.

Generalization decrements as such have been shown in a number of experiments in which various drugs served as cues (see Overton,
A proper design for such experiments is as follows (Miller, 1957). G. 10 is administered no drug in Ph. 1, whereas G. 20 does receive a drug in Ph. 1. G. 02 receives the same drug in Ph. 2, whereas G. 01 receives no drug in Ph. 2. A generalization decrement is evaluated as an interaction such that learning carrying over into Ph. 2 is poorer for Gs. 12 and 21 than for Gs. 11 and 22. The occurrence of such an interaction establishes that the drug affects performance because of the procedural change in drug administration, since drug effects unrelated to the change per se cancel out in evaluating the interaction. The effect of such a change may be regarded definitively as a generalization decrement unless some operational criterion be specified for distinguishing generalization decrements from withdrawal symptoms for G. 21.

The concept of generalization applies to drives as well as to cues. Thus, for example, in an experiment with rats, bar pressing for food followed a descending generalization gradient with changes along a dimension of hunger (hours of food deprivation) (Yamaguchi, 1952). This generalization gradient was established as such with an experimental design resembling the paradigmatic design just described for drug investigations, except that more than two points along the hunger dimension were investigated.

The results of the following experiment considerably extend the generalization findings of the usual type. In Ph. 1 rats were trained to avoid shock by going to the opposite compartment of a shuttlebox (Bovet, Renzi, & Oliverio, 1969). For Gs. 1 and 2, S+ was a steady tone. For G. 3 S+ was a pulsating tone.
In Ph. 2, instead of the tone presented in Ph. 1, a steady light, or a steady tone and steady light together, were presented for Gs. 1 and 2 respectively. For G. 3 a light was presented that pulsed at the same rate as did the tone in Ph. 1. In Ph. 3 the steady light alone was presented for Gs. 1 and 2, and the pulsating light was presented for G. 3.

Toward the end of Ph. 1, all the rats avoided the shock fairly consistently. It would seem unlikely that this same level of performance could have been trained to the light in Phs. 2 and 3, since these phases were considerably shorter than Ph. 1. Indeed, almost no avoidance to the light occurred for G. 1 in Ph. 3. However, for Gs. 2 and 3, the avoidance performance attained in Ph. 1 continued at the same high level in Phs. 2 and 3.

For an additional group of rats, essentially the same procedure was followed as for G. 1 above, except that the required response was bar pressing in another apparatus. In contrast to the findings for G. 1, avoidance by bar pressing continued at the same high level to the light in Phs. 2 and 3 as to the tone in Ph. 1. The shuttlebox findings above agreed with those in cited mouse experiments. To compare the above results between Gs. 1 and 2 in the shuttlebox, performance in Ph. 3 indicates that the concomitant presence of S+ and the light facilitated generalization from S+ to the light, but ideally the experiment should have included control groups for which Ph. 1 was omitted to assess the degree to which the effects observed in Ph. 3 represented generalization actually due to training with the tone in Ph. 1.
IB-3.3. Darwinian Cue Effects

At the start of a training procedure, the specific stimuli to serve as $S+$ and $S-$ may affect behavior differently than would other stimuli functioning as $S+$ and $S-$. In particular, the makeup of the cues may determine whether the target response occurs or fails to occur as required in order for the incentive contingency to be fulfilled. The stimulus-specific character of the cues may thus determine whether behavior initially varies appropriately in the Darwinian sense—i.e., in such a way that the relevant incentive contingency can affect performance (cf. S. IA-4.6).

What determines whether the specific stimuli posited as $S+$ and $S-$ will affect behavior differently at the start of a new training regimen than would other stimuli in the capacity of $S+$ and $S-$? Such a difference could arise through preliminary learning—specifically, through shaping, generalization, and/or processes to be discussed from Ch. 6, Part IB, onward. Even in the absence of preparatory anthropogenic training procedures such as shaping, it is probably impossible operationally to rule out the possibility that such differences represent preliminary learning. However, insofar as such learning is not shown empirically, it is empirically accurate to say only that cues may have stimulus-specific effects on initial performance.

Suppose that preliminary learning is, in fact, the basis for a stimulus-specific cue effect on initial performance. Such learning would be likely to be response-selective in the Darwinian sense, i.e., to be associated with one response without necessar-
ily being associated with other responses, in view of the earlier discussion in S. IB-2.1. The occurrence or direction of an initial stimulus-specific cue effect would thus be likely to depend on the response involved. That stimulus- and response-specific effects are common is evident. For example, hunger and estrus but not thirst increase motor activity (Bindra, 1968), and hungry rats groom more but sleep less than do thirsty rats (Bolles, 1965).

IB-3.4. **Stimulus-specific Cue Effects on Learning**

As training progresses, stimulus-specific cue effects on learning may emerge. Such specificity cannot be ascribed to prior stimulus-specific cue effects on performance, as above, where such specificity of ongoing learning obtains even though the required response occurred readily from the start of training. Even under such conditions, however, stimulus-specific cue effects on ongoing learning are readily observable, as in the following prototype experiment. Cats could press either of two panels each displaying a rectangle (Hara & Warren, 1961). In any given phase the rectangles differed from one another along one or a combination of three dimensions: width-height ratio (*orientation*), size, and brightness.

Neither of the rectangles changed along these dimensions within any phase. However, the left-right positioning of the rectangles was reversed from trial to trial. Thus, for one of the two left-right choice responses of pressing a panel, \( S^+ \) comprised the two rectangles in one of the two left-right arrangements, and \( S^- \) comprised the rectangles in the opposite arrangement. \( S^+ \) and \( S^- \)
thus differed from each other along a position dimension within each phase. S+ for one choice response was S- for the other choice response, and vice versa. The correct choice response resulted in presentation of food reward.

Only one group of animals was trained. Different sets of cues were presented in different phases, and the right-left differences between the rectangles' orientation, size, and brightness served as the three so-called "relevant" dimensions along which S+ and S- were changed among phases. Within each phase differentiation of choice performance was measured as the inverse of incorrect responses (nonrewards) and reflected the number of trials required for learning.

In comparisons among phases faster relearning was found with greater differences along the relevant dimensions—for example, with a greater size difference between the two rectangles. With the two rectangles differing along only one relevant dimension at a time, six such differences, two per relevant dimension, were found such that three relatively large differences, one per relevant dimension, produced equally high differentiation. The other three relatively small differences between the rectangles produced equally lower differentiation.

The animals were then retrained over a number of phases in which differentiation was measured for all of the six differences singly and in all possible combinations. In comparisons among phases differentiation was again greater with greater differences between the rectangles along each relevant dimension. Moreover,
the differences along each dimension had an additive effect on differentiation when the two rectangles differed along more than one relevant dimension. Any single-group retraining procedure such as the one in this experiment is called a learning set procedure.

In another experiment relatively faster learning of a wheel-turning avoidance response was found with a relatively greater parametric intensity of S+, a light (Kessen, 1959). Similarly, high frequency pure tones have been found to be more effective than low frequency pure tones as S+'s for avoidance learning by rats (Dewson, 1965). The particular S+ and S- used for training have been found to affect differentiation in various other experiments (e.g., Miller & Greene, 1954; Myers, 1959, 1962, 1964).

A stimulus-specific cue effect on ongoing learning may depend on the response being trained, as the following experiment shows. For G. 10 of dogs, S+ and S- were tones emanating from speakers respectively above and below a dog (Lawicka, 1964). For G. 20 S+ and S- were tones of respectively different pitch emanating from a single speaker. The incentive was food reward.

For G. 01 the trained response involved straight approach toward the food, whereas for G. 02 left and right choice responses were trained. For G. 02 the S+ and S- for one choice were simultaneously the S- and S+, respectively, for the other choice. Only Gs. 12 and 21 showed differentiation to any significant extent. Analogous results were obtained in further experiments (Dobrzechka & Konorski, 1967, 1968; Konorski, 1967; Szwejkowska, 1967).
IB-3.5. Discrimination

Differentiation is often the outcome of "discrimination." Discrimination is defined as a loss of generalization from an S+ to an S- and can thus be demonstrated in either of two ways.

First, to return to the heart-rate experiment discussed previously in S. IB-3.1, suppose that control groups of rats had been presented with an S- during only the later part of training but had otherwise received the same treatment as did the two experimental groups actually run. If it had then been shown that differentiation for these experimental groups was greater than for the control groups, discrimination would have been shown.

Since such control groups were not run, discrimination was not demonstrated in the experiment. A second method for showing discrimination also did not indicate discrimination in this experiment. This method involves a within-groups effect and is illustrated in the following example.

In a common discrimination paradigm, response speed is measured for hungry rats each given training trials in both black and white runways in an irregular sequence (e. g., see Amsel, 1967). Runway albedo appropriately balanced serves as S+ and S- for food reward in the goal box. Early in training, performance progressively increases with both S+ and S-, but later, performance to S- progressively decreases back to its initial level as the number of training trials increases. Such a decrease constitutes discrimination, regardless of whether S- is presented throughout training as in this case or is irregularly alternated with S+ after initial
training with S+ alone.

Runway response speeds are often measured separately for the start area, the "run" area between the start and goal areas, and the goal area (e.g., see Amsel, 1967). When asymptotic response speed has essentially been reached, rats run progressively faster on S+ trials as they approach the goal box. At this time speed to S+ minus speed to S- is greatest in the goal area and is least in the start area in the discrimination paradigm just described. Interestingly, the opposite relationship holds early in training, before speed to S- decreases: speed to S+ minus speed to S- initially becomes positive in the start area, negative in the run area, and more negative in the goal area and then becomes positive in the run area before becoming positive in the goal area.
Chapter 4

TRACE CUES AND TEMPORAL CUES

IB-4.1. Trace Cues from Preceding Trials

When rats are given training trials in a single runway with food reward on certain trials, stimuli from the previous trial may serve as trace cues. For example, in an experiment in which rats in G. 1 were given food reward for entering the goal box on every other trial, reward (i.e., a goal box containing reward) and non-reward (i.e., a goal box containing no reward) on the preceding trial acted apparently as $S-$ and $S+$ respectively in that asymptotic response speed was substantially greater on rewarded trials than on nonrewarded trials (Bloom & Capaldi, 1961). These rats showed apparent discrimination in that response speed first increased to both $S+$ (previous nonreward) and $S-$ (previous reward) and then decreased to $S-$. Since $S+$ and $S-$ were not balanced in the manner described earlier in S. IA-5.2, the question arises as to whether this effect was true differentiation and discrimination or was instead due to recency of reward per se. Two lines of evidence indicate that the observed effect was indeed true differentiation.

1. Hungry rats in G. 2 were alternately given food reward on two consecutive trials and no food reward on two consecutive trials. For this group reward and nonreward were thus signalled equally often by each of the stimuli that served as $S+$ and $S-$ for G. 1. For G. 2 response speed on reward as well as nonreward trials did not differ systematically from response speed for G. 1 on
reward trials, and at no time during training was there a departure from this congruity. This result indicates no effect of reward vs. nonreward on the previous trial for G. 2 and thus indicates that the differentiation observed for G. 1 was genuine, i.e., not due to recency of reward.

2. An alternative to balancing S+ and S- is to use one of the control procedures that were mentioned in S. IA-5.2. A control procedure particularly suited to the present experiment would have been a partial reinforcement procedure differing from the procedure for G. 1 only in respect that reward and nonreward trials would have occurred in an irregular sequence with partial reinforcement. A large number of experiments have used partial reinforcement procedures (e.g., for references see Jenkins & Stanley, 1950; D. J. Lewis, 1960), and in such experiments reward vs. nonreward on the preceding trial does not affect performance comparably to the effect shown for G. 1 in the present experiment. The differentiation shown by G. 1 would thus seem to have been more than just apparent differentiation (cf. S. IA-5.2).

In another experiment each rat in Gs. 1 and 2 was alternately given food reward on two consecutive trials and no food reward on two consecutive trials (Capaldi, 1970), as was done for G. 2 in the preceding experiment. For both groups in the present experiment, half the trials were in a black runway and half were in a white runway. For G. 1 the black–white sequence was irregular, and response speed for these rats did not differ between reward and nonreward trials. The rats in G. 2, however, ran in the opposite
runway from each trial to the next, and these rats showed differ-
entiation in terms of food-reward learning. Trace differentiation
thus failed to occur between previous reward and previous nonre-
ward alone, as was the case for G. 2 in the preceding experiment,
but did occur between previous reward and previous nonreward in
combination with albedo.

Trace cue effects have been shown for lever pressing as well
as for runway responses. Whereas lever pressing in the usual
"free-responding" situation is not constrained, lever pressing in
the "discrete-trial" paradigm is constrained, for example, by re-
moving the lever, and only one lever press is allowed per given
time interval. The discrete-trial paradigm for lever pressing is
thus more analogous to the runway paradigm than is the free-
responding paradigm. The appropriate performance measure for
discrete-trial lever pressing is response speed, i. e., the in-
verse of latency for lever pressing (e. g., cf. Leonard, reported
in Capaldi, 1967).

In a discrete-trial lever-pressing experiment, rats alter-
nately received food reward on one trial and no food reward on two
consecutive trials (Wall & Goodrich, 1964). Thus, reward on the
preceding trial signalled nonreward on the ongoing trial, whereas
nonreward on the preceding trial signalled reward on the ongoing
trial with 50% reliability. Correspondingly, once learning oc-
curred, performance was lower following reward than following non-
reward. Furthermore, performance on the second nonreward trials
(following nonreward) averaged less than performance on the reward
trials (also following nonreward) and thus indicated a trace cue effect from the trial before the preceding trial. However, performance on the second nonreward trials was greater than performance following reward, i.e., on the first nonreward trials. In an analogously designed runway experiment with rats, response speed did not differ between the reward and second nonreward trials, both of which followed nonreward (Capaldi, 1967). Whereas response speed on these trials increased to a single asymptotic level, response speed following reward, i.e., on the first nonreward trials, first increased and then decreased and thus indicated discrimination.

In another experiment rats were consistently given food or no food in separate blocks of discrete lever-pressing trials (Leonard, reported in Capaldi, 1967). Gs. 1 and 2 were given respectively 12 and 24 trials per nonreward block and were given 7 trials per reward block. Performance for G. 2 was reported as separate averages for the first and last 6 trials of the nonreward block. After training had progressed, this group's performance was greater on the last 6 nonreward trials than on the first 6 nonreward trials, but both of these performance values were less than performance for G. 1 on the first 6 nonreward trials. A whole sequence of preceding nonreward trials thus seemed to contribute to differentiation, at least for G. 2.

When no reward is given during extinction training following acquisition training with partial reinforcement, a partial reinforcement extinction effect is frequently seen (e.g., see Jenkins
& Stanley, 1950; D. J. Lewis, 1960). That is, animals who were given partial reinforcement perform at a higher level during extinction training and thus show poorer extinction than do animals who were consistently rewarded during acquisition training. Various explanations of the partial reinforcement extinction effect have been advanced (e.g., see D. J. Lewis, 1960). Perhaps the most tenable explanation, in view of the results indicated above, is that this effect represents a trace cue effect (Capaldi, 1966). The argument is that the relatively greater extinction performance of partially reinforced animals represents their responding to trace cues of nonreward that sometimes signalled reward during acquisition training. Performance during extinction training is relatively poorer for continuously reinforced animals because prior response-contingent nonreward did not signal reward for them.

IB-4.2. Trace Cues and Relearning

In several experiments animals have been given successively alternated blocks of reward acquisition and extinction training trials. The general result is that asymptotic performance is approximated in fewer acquisition trials within successive acquisition blocks (see Capaldi, 1967). Such facilitation of reacquisition may take place largely within the first block of reacquisition training trials (North & Morton, 1962).

Such facilitation is thought to represent an effect of trace cues (Capaldi, 1967). The reasoning is that performance facilitation during reacquisition training comprises responding to trace
cues of reward that signalled reward during previous acquisition training and that were absent and therefore not nullified during extinction training. Findings in the following paradigm qualify this idea.

In Ph. 1 of runway training, the weight of food reward is either greater or less for G. 1 of rats than for G. 2 (see Spear, 1967). In Ph. 2 the weight of food reward differs from that for either group in Ph. 1 and may be zero as a special case. In Ph. 3 the weight of food reward is equal between the groups and is the same as in Ph. 1 for, say, G. 2. Then, after the first trial in Ph. 3, response speed is greater for G. 2 than for G. 1, even for rats receiving no food reward (a weight of zero) in Ph. 3.

This result does not seem to depend particularly on the number of trials in Ph. 2. Such dissociation might be expected if the performance difference in Ph. 3 reflects a generalization decrement for G. 1, on the grounds that the same trace stimuli that previously signalled response-contingent reward are reinstated only for G. 2 in Ph. 3. However, since the performance difference in Ph. 3 occurs even with no reward, the trace stimuli reinstated in Ph. 3 facilitate performance apparently through their familiarity per se, i.e., simply because they appeared in Ph. 1, and not solely because they served previously as cues in the operational sense.

The foregoing effects pertain to response speed after the first trial in Ph. 3, as mentioned. The first trial in Ph. 3 is quite another matter. If this trial follows the last trial in Ph.
by a time interval much longer than the within-phase intertrial intervals, response speed is greater on the first trial of Ph. 3 for whichever group received the greater magnitude of reward in Ph. 1, even though response speed is about equal between the groups toward the end of Ph. 2. In addition, average response speed for both groups may be greater on the first trial of Ph. 3 than on the last trial of Ph. 2.

In a variation of the foregoing paradigm, an experimental group of rats is given training with no reward in Ph. 1, whereas a control group has no Ph. 1 at all. Then, if the first trial in Ph. 3 follows the last trial in Ph. 2 by a time interval sufficiently longer than the within-phase intertrial intervals, runway response speed on the first Ph. 3 trial is greater for the control group than for the experimental group. Analogous findings have been obtained when the reward contingency in choice paradigms is reversed between Phs. 1 and 2 for rats in an experimental group. Control rats having received no Ph. 1 training are subjected to the same Ph. 2 training procedure concomitantly given the experimental rats, and a time interval longer than the within-phase intertrial intervals elapses between the last trial in Ph. 2 and the first trial in Ph. 3. Then, even if trained choice performance was about equal between the groups on the last trial of Ph. 2, choice performance of the trained response may be lower for the rats in the experimental group than for the control rats on the first trial in Ph. 3. Such a difference obtains only for rapidly learned responses and increases as the parametric time interval increases between
the last trial in Ph. 2 and the first trial in Ph. 3 for both groups.

**IB-4.3. Temporal Differentiation**

A temporal parameter may serve as a cue, as the following experiment illustrates. What will be called $S_0$ and $S_1$ were the usual physical stimuli in this experiment (Zimmerman, 1961). For Gs. 1 and 2 of rats, 36 sec. elapsed between onsets of $S_1$. Each such interval consisted of four subintervals, which will be designated as follows for present purposes: $T_a =$ the first 6 sec.; $T_0 =$ the next 12 sec.; $T_1 =$ the following 12 sec.; and $T_b =$ the last 6 sec.

$S_1$ was immediately terminated and $S_0$ was thereupon presented at the start of $T_b$ or when a lever was pressed, whichever occurred first in the 36-sec. interval. Presentation of $S_0$ continued until the next onset of $S_1$. A single lever press would yield food during $T_0$ or $T_1$ for G. 1 but only during $T_1$ for G. 2. Food reward was never available during $T_a$ or while $S_0$ was being presented.

The parametric intervals $T_0$ and $T_1$ can be regarded as stimuli insofar that their contingency-related property served as a treatment variable (cf. Ss. IA-3.1 and IA-3.2), and thus, in principle, they could have served as cues for G. 2. Hence, in principle, differentiation between $T_0$ (as "T-") and $T_1$ (as "T+") was possible for G. 2. Moreover, for G. 1 the training contingency was effective either during $T_0$ and $T_1$ both or only during $T_0$, depending on whether the lever was pressed. Thus, for G. 02 differentiation between T- and T+ could be distinguished in reference to apparent or
balanced differentiation for G. 1 (cf. S. IA-5.2). True temporal differentiation for G. 2 was shown in that lever pressing rate for both groups peaked shortly after their respective training contingencies went into effect.

The procedure differed between Gs. 1 and 3 in respect that the program skipped ahead to the start of $T_b$ whenever a rat in G. 3 would press the lever before that time. The rats in G. 3 thus received reward more frequently than did their counterparts in G. 1. Correspondingly, lever pressing rate at its peak was higher, and the peak occurred earlier in $T_0$, for G. 3 than for G. 1.

The purpose of testing G. 3 was to assess the effect of reward frequency separately from the effect of temporal cues, since these factors are confounded with each other in most experiments dealing with possible temporal cue effects. In one experiment, for example, rats trained in a runway received food only if they took more than a certain amount of time to reach the goal box (Logan, 1960). Response speed was accordingly slow, but it is not clear why.

**IB-4.4. Temporal Trace Cues**

Whereas the lever-pressing experiment described in the preceding section dealt with temporal cues that were delayed cues, the following experiment was concerned with temporal trace cues. Rats were trained with food reward that was available on every other trial in a runway (Minkoff, reported in Capaldi, 1967). For Gs. 10 and 20 in Ph. 1, the time between any nonreward trial and
the next (reward) trial was 30 sec. or 8 min. respectively, and the time between any reward trial and the next (nonreward) trial was respectively 8 min. or 30 sec. In Ph. 2 the intertrial intervals were consistently 30 sec. or 8 min. for Gs. 01 and 02 respectively, and no food was given.

In terms of runway response speed, no main effects and a positive interaction emerged in Ph. 2. Response speed in Ph. 2 was thus relatively high or low after intertrial intervals that had ended respectively with a reward or nonreward trial in Ph. 1. The parametric durations of these intervals may be regarded as stimuli (cf. Ss. IA-3.1 and IA-3.2), and thus the interaction resembled the type of interaction whereby cue effects can be established, as described earlier in S. IA-5.2. Although the observed performance difference between the stimuli, the intertrial durations, was assessed during extinction training and between separate subgroups (11 vs. 12 and 21 vs. 22), these two peculiarities of the present experiment are superficial—the first because performance during training does not have to be assessed simultaneously with the occasions on which the training contingency is in effect (cf. S. IA-4.1). The observed interaction thus established the intertrial durations as temporal cues.

Although the subgroup-related differences in response speed were rather marked early in Ph. 2, extinction in Ph. 2 took the form that the response speeds of the four subgroups decreased to an essentially uniform level by the end of Ph. 2. In Ph. 3 the intertrial intervals from Ph. 2 were reversed between Gs. 01 and 02,
and a negative interaction emerged. Thus, once again response speed was relatively augmented or diminished depending on whether the ongoing parametric intertrial durations had signalled the availability or unavailability of food reward in Ph. 1. Moreover, this temporal cue effect remained latently intact throughout extinction training with the converse intertrial durations in Ph. 2.

IB-4.5. Schedules of Reward and of Punishment

In a common training paradigm, a response, typically a bar press, yields reward, whereupon additional responses will not yield reward until the end of a fixed (constant) time interval. The interval begins either with the rewarded response or at the time when reward previously became reavailable. Either type of program is commonly called a fixed-interval (FI) schedule and is designated FI-2, for example, if the fixed interval with reward unavailable is 2 min. For practical purposes the two types of FI schedules are interchangeable (cf. Ferster & Skinner, 1957).

With FI schedules, performance, typically bar pressing rate, is usually higher when reward is available than when it is unavailable. Thus, in view of the foregoing discussion of temporal cues, it will be assumed for discussion purposes that the temporal cues T+ and T- serve as S+ and S- in FI schedules. By this assumption T- is the nonreward interval following a response, and T+ is the time between the end of T- and the subsequent response. The relatively low response rate during T- forms what is commonly called an FI scallop. Reward with variable-interval (VI) schedules
is unavailable for varying intervals of time for each subject, although the average interval is fixed. A VI schedule was followed for food reward in the bar-pressing experiments that were discussed in S. IB-1.3 with regard to passive avoidance of shock.

A common paradigm is Sidman avoidance training. In Sidman's (1953) original experiment rats could press a bar to avoid shock that otherwise occurred after parametric time intervals of separable duration following a previous response or shock respectively. The parametric response-shock and shock-shock intervals regulated bar pressing rate according to the frequency of punishment. This regulation apparently did not depend on temporal cue effects (Sidman, 1954).
Chapter 5

FEEDBACK STIMULI

IB-5.1. Shock Contingent on a Formerly Rewarded Response

Many experiments have shown that performance of a trained response is facilitated when rats receive podal electric shock between the start and goal boxes at the two ends of a straight runway. In one experiment, for example, hungry rats were rewarded with food in the goal box in Ph. 1 (Brown, 1965). The rats in G. 1 were never shocked, whereas in Phs. 2 and 3, the rats in G. 2 would always be shocked in the runway section midway between the start box exit and the goal box entrance. In Ph. 2 shock intensity was gradually increased from trial to trial (cf. Ss. IB-8.6, IB-8.8, and IB-13.4). Concomitantly, hunger magnitude and the weight of the food were gradually decreased. Finally, in Ph. 3, the shock was of full intensity, and the rats were not shocked and were given no food reward.

Extinction of the runway response was considered to have occurred when a rat would take at least 60 sec. to run to the goal box. Rn was considerably greater for G. 2 than for G. 1. In fact, in G. 1, only 1 rat out of 21 continued to run throughout most of Ph. 3, and response speed for this rat progressively decreased from trial to trial in Ph. 3. However, response speed progressively increased for G. 2 as Ph. 3 progressed. Shock thus functioned as a reward for G. 2.

This finding suggests that shock acted as a feedback stimu-
Shock was not conclusively demonstrated to be a feedback stimulus, since a conclusive demonstration would have required two control groups that were given no food during the experiment (cf. S. IA-5.4). If two such groups had been run, shock might have been a punishment for one of these groups relatively to the other, in view of the findings that were discussed in S. IB-1.3. Alternatively, the animals in both groups might have stopped running altogether, in which case Rn would have been zero for both groups. In either case—if shock had served as a punishment, or if Rn had been zero—the actual results of the above experiment indicate that a Shock x Food interaction would have been obtained, thereby establishing shock as a feedback stimulus (cf. S. IA-5.4). In fact, an interaction of this sort was obtained in an experiment discussed in the next section.

Ordinarily electric shock can function as a punishment or as a drive, as was discussed in Ss. IB-1.3 and IB-1.4. A noteworthy feature of the preceding experiment and of other experiments discussed shortly may be that shock was in a position to act both as a punishment and as a drive during extinction training. That is, assuming that in these experiments shock had as usual the capacity to function as a punishment and as a drive, shock was a punishment for running into the shock and was a drive for running out of the shock.

During extinction training, increased running speed through the shock might thus have been ordinary escape. Moreover, in the runway section preceding the shock area, increased running speed
should increase an animal's momentum, should therefore increase running speed through the shock, should consequently decrease the duration of response-contingent shock, and might thus have functioned as partially effective active avoidance. However, this "avoidance and escape" model is not sufficient to account for the effect of shock as a feedback stimulus in at least some cases, as will be discussed in S. IB-5.6. Nevertheless, an "avoidance and escape" effect might still augment the effect of shock as a feedback stimulus. Except as noted otherwise, all the experiments described in this chapter involved shocking rats between the start and goal boxes of a straight runway on each extinction trial.

A feedback stimulus by definition facilitates incentive-supported learning, and extinction by definition implies a loss or reversion of such learning. Hence, the definition of feedback stimulus implies that a feedback stimulus as such might eventually lose its effect during extinction training. However, feedback stimuli often enhance residual acquisition learning early in extinction training as in the preceding experiment and in other experiments to be discussed, whereas learning carried over from acquisition training usually diminishes progressively when a feedback stimulus is not presented during extinction training. Acquisition learning might thus be expected to undergo eventual extinction more precipitously with a feedback stimulus than without a feedback stimulus. Such an effect appeared in some experiments as indicated in the following sections.
IB-5.2. Shock Contingent on Quondam Avoidance and Escape Responses

In the active avoidance and escape experiments described below, response-contingent shock in extinction training facilitated runway performance and thus served at least temporarily as a reward as in the experiment described in the preceding section. In acquisition training of avoidance and escape, shock was applied in the start box and runway but not in the goal box. Shock onset was delayed for a set time in the case of avoidance acquisition training. In one experiment with rats, shock was superimposed on extinction training, and Rn was greater after avoidance acquisition than after escape acquisition (Hurwitz, Bolas, & Haritos, 1961). The reliability of such a difference was not established until a later experiment (Beecroft & Brown, 1967) to be discussed in S. IB-5.4.

In another experiment each rat was given 50 avoidance acquisition trials with shock occurring 10 sec. after the rat was placed in a runway apparatus (Whiteis, 1955). On each extinction trial the six rats in G. 1 received no shock, whereas the six rats in G. 2 were shocked in the runway segment preceding the goal box. With an extinction criterion of 2 min., extinction occurred for two rats in G. 1 and for four rats in G. 2.

Response speed gradually decreased for G. 1 but increased rapidly to a maximum for G. 2 as extinction training progressed. Thus, on the 80th of 250 extinction trials per rat, average latency was 28 and 1 sec. for Gs. 1 and 2 respectively. The G. 2 rats that met criterion did so suddenly after running rapidly on the
preceding trial.

Two phases of extinction training, Phs. 2 and 3, followed avoidance acquisition training in another experiment (Melvin & Smith, 1967). No rats met a 40-sec. criterion of extinction in either phase. The rats in one group were shocked during Ph. 2 but not during Ph. 3, whereas the rats in another group were shocked during Ph. 3 but not during Ph. 2.

In Phs. 2 and 3, response speed was higher for the group receiving shock during the particular phase. On the average, the absolute response speed difference between the groups was about the same in Ph. 2 as in Ph. 3, though response speed for both groups together averaged higher in Ph. 3 than in Ph. 2. In each of these phases, response speed progressively increased for the shocked group and progressively decreased for the unshocked group.

After avoidance acquisition training in another experiment, Rn was equally high for two groups that received shock on respectively 20% or 100% of the trials in extinction training (Beecroft, Fisher, & Bouska, 1967). However, in a different experiment proportionately more shock trials in extinction training facilitated responding after either avoidance or escape training for separate groups of rats (Bender & Melvin, 1967). Thus, not only does 100% shock in extinction training facilitate performance in comparison with 0% shock, as in most of the experiments discussed in this chapter, but this relationship may be monotonic along a dimension of percentages between 0% and 100%.

In an escape experiment rats in separate groups were shocked
on 33%, 67%, or 100% of the trials in acquisition training and on 0%, 33%, 67%, or 100% of the extinction-training trials in a factorial design (Melvin, 1964). With regard to the extinction main effect, $R_n$ increased with the parametric percentage of shock trials in extinction training. Although no acquisition main effect was prominent in terms of performance in extinction training, an interaction occurred such that the aforesaid extinction effect was greater with proportionately more shock trials in acquisition training. This interaction is of the type whereby a feedback stimulus may be definitively characterized as such (cf. S. IA-5.4), although the definitive interaction is based on comparisons between 0% and 100% presentation of the incentive and of the feedback stimulus, rather than among intermediate percentages. In another escape experiment, rats suddenly stopped running after an 18-min. intertrial interval preceded by 30-sec. intertrial intervals (Martin, 1967) (cf. S. IB-4.4).

IB-5.3. Negative Findings

A few investigations have failed to show unequivocally that shock in extinction training facilitates performance. However, these investigations have not included control groups for whom the incentive contingency was omitted in the initial experimental phase. Thus, these investigations have not shown whether or not shock in extinction training interacts with the acquisition incentive, and therefore they have not shown whether shock fails to function as a feedback stimulus when it fails to facilitate per-
formance in extinction training.

In one of these investigations, rats were given avoidance or escape training in separate experiments (Seward & Raskin, 1960). In both experiments the same extinction-training procedure was followed. Subgroups were shocked on 0%, 50%, or 100% of the trials in extinction training.

Proportionately more shock during extinction training produced a lower Rn, although there were hints of a greater response speed with proportionately more shock in extinction training. Perhaps the results were negative due to procedural differences between this experiment and those other experiments with positive results. Two differences are apparent. First, 190 v. shock was used in the present case. This voltage is higher than the voltages usually used. Second, shock during extinction training was turned on in the two middle feet of the runway when a rat would reach the midpoint. The grid was thus electrified behind as well as in front of a rat reaching the critical point. Usually the shock circuit is already turned on before a rat leaves the start box during extinction training with shock.

Two other experiments with rats did not use a runway but did not differ procedurally in any clearly consequential way from the runway experiments discussed in the two preceding sections. For example, shock during extinction training was applied only between start and goal areas as in these runway experiments (Moyer, 1955, 1957). In one of the two experiments, avoidance training was given for 10, 50, or 110 trials for separate groups of rats (Moyer,
After 110 acquisition training trials, shock during extinction training resulted in a higher Rn (not significant) with a 10-sec. criterion, but resulted in a lower Rn with a 5-min. criterion, than did no shock during extinction training. During extinction training, response speed for the shocked rats was greater with 15, 30, or 60 days between acquisition and extinction training than with 1 intervening day. Also, Rn was decreased when a novel stimulus was present at the shock site.

After escape training in the second experiment, shock during extinction training resulted in parametrically greater response speed, a higher Rn (not significant), less performance recovery after time-out from the experiment, greater variance in Rn, and a more abrupt fall in performance, than did no shock during extinction training (Moyer, 1957). A few avoidance experiments besides those discussed here have failed to show that shock in extinction training facilitates performance when such an effect might be expected. Possible reasons for these negative results have been suggested elsewhere (Brown, 1969).

IB-5.4. Running in Preshock Runway Segments

The "avoidance and escape" model given earlier in S. IB-5.1 implies that response speed should increase in the runway segments preceding the segment with shock. In an avoidance experiment bearing on the issue, response speed during extinction training was measured for a group of shocked rats in the preshock runway segments and for an unshocked group in the same segments (Beecroft,
1967). From trial to trial response speed progressively declined in extinction training for the unshocked group but not for the shocked group. Rn was several times greater for the shocked group than for the unshocked group.

In another experiment, for rats receiving 55 v. shock during avoidance acquisition training, Rn was 12, 23, 36, and 25 for groups receiving respectively 0, 40, 55, and 75 v. shock during subsequent extinction training, although response speed increased uniformly with increased shock voltage in extinction training (Beecroft, Bouska, & Fisher, 1967). After avoidance acquisition training with 70 v. shock, however, Rn was greater for a group receiving 70 v. shock during extinction training than for a group concomitantly receiving 55 v. shock. In summary, Rn decreased parametrically with a voltage change from acquisition training to extinction training, but a contrary finding was obtained in the following experiment, which involved escape unlike the experiment just described.

Rats in each group were initially trained to escape 60 v. shock by running through a circular runway and jumping out at the end (Gwinn, 1949). On each trial of extinction training, 120 v., 60 v., or no shock was administered to three separate groups of rats in the final segment of the runway. Both response speed in a preshock segment and Rn were greatest for the 120 v. group and least for the no-shock group.

During extinction training in another escape experiment, response speed in the preshock runway segments progressively in-
creased from trial to trial for rats receiving shock, and none of these rats met the extinction criterion (Beecroft & Bouska, 1967). For other rats receiving no shock during extinction training, response speed in the same runway segments progressively decreased. Some of the rats given no shock met the extinction criterion.

In a different experiment three alley segments between the start and goal areas were distinguished from each other (Brown, Martin, & Morrow, 1964) and will be designated here as Segments A, B, and C, with Segments A and C being closest to the start and goal boxes respectively. On each trial in extinction training following escape training, G. 1 of rats was not shocked, G. 2 was shocked in Segment C only, and G. 3 was shocked in Segments A, B, and C. Mean response speed during extinction training was higher for G. 3 than for G. 1 in all segments. Within each of these groups, mean response speed was about the same in each segment as in the other segments. For G. 2, however, mean response speed was about the same as for G. 1 in Segment A, was about the same as for G. 3 in Segment C, and was intermediate in Segment B. As extinction training progressed, response speed progressively decreased for G. 1, progressively decreased to a lesser extent for G. 2, and did not decrease for G. 3.

On each acquisition training trial in another experiment, shock onset was delayed for 0, 1, 2, or 4 sec. for respective groups of rats (Beecroft & Brown, 1967). The 0- and 4-sec. procedures were typical escape and avoidance training procedures respectively, but with the 1- and 2-sec. procedures, the rats could
not reach the end of the runway before onset of shock. The 1- and 2-sec. procedures were thus "avoidance-escape" procedures in that a response occurring earlier in the runway decreased the duration of the shock and was thus a partially effective avoidance response, whereas a response later in the runway was an escape response.

At the end of acquisition training, response speed in what was to be the preshock segment was greatest for the 1-sec. group and was least for the 4-sec. group. During extinction training, all the rats were shocked in the runway segment adjacent to the goal box. Rn was least for the 0-sec. group. At the end of extinction training, response speed in the preshock segment was greatest for the 1-sec. group and was least for the 0-sec. group.

IB-5.5. Shock Superimposed on Extinction Training for Shuttling

All the preceding experiments in this chapter involved shocking rats between start and goal areas on each trial of extinction training. The "avoidance and escape" model proposed earlier in S. IB-5.1 thus applies to all these experiments. However, in a few experiments this model does not apply in that response-contingent shock that was inescapable facilitated performance in extinction training. Such experiments are thus relevant to the experiments that have already been discussed.

In several of these experiments, dogs were trained to avoid shock by jumping a barrier in a shuttlebox (see Brush, 1957). During subsequent extinction training, each animal was given a fixed-
duration shock if the animal jumped to the opposite compartment of the shuttlebox. Shocking the animals in this manner facilitated shuttling during extinction training. In the experiments in this series, the shock in extinction training was considerably more intense than that in most of the runway experiments that have been discussed in this chapter.

In one shuttlebox experiment of the series, S+ onset consisted of raising the gate between compartments and turning off the light over the animal in the shuttlebox (Brush, 1957). For separate groups of animals, 10 or 200 extinction-training trials without shock were interpolated between acquisition training and an extinction-training phase in which shock was contingent on shuttling. Only a small proportion of the animals met the extinction criterion during the extinction training without shock. During 100 trials of the extinction training with shock, proportionately fewer animals met the extinction criterion with the greater number of interpolated extinction-training trials without shock. This same differential effect was also seen in an earlier experiment in which 100 extinction-training trials with shock followed 10 vs. 200 interpolated trials of extinction training without shock (Solomon, Kamin, & Wynne, 1953). Among the animals that did meet the extinction criterion in the later experiment (Brush, 1957), jumping was observed to cease abruptly from one trial to the next. Such abrupt extinction contrasts with the gradual performance decrease that occurs for dogs given extinction training without shock.
In the prototype experiment in the series, the animals were frequently observed to bump into the far wall of the compartment in which they were to receive shock (Solomon, Kamin, & Wynne, 1953). These animals jumped much more quickly and vigorously than did animals not receiving shock in extinction training. In another experiment in which animals were trained to jump a barrier in a shuttlebox, shock in extinction training again resulted in increased preformance preceding eventual extinction (Black & Morse, 1961). After relatively more prolonged avoidance acquisition training in this experiment, correspondingly more prolonged extinction training with shock was required for extinction to occur.

It has been found that avoidance acquisition learning is diminished, and subsequent extinction is facilitated, with similar as opposed to dissimilar start and goal boxes (Denny, Coons, & Mason, 1959; Knapp, 1965). The findings of the aforementioned shuttlebox experiments might thus have been related somehow to the fact that the two compartments of a shuttlebox are similar to each other in appearance. Also, in the preceding shuttlebox experiments, animals learned during acquisition training to leave a compartment after entering it, and during extinction training they were shocked at the sites they had been trained to leave. Shock during extinction training was thus contingent on a response learned in acquisition training and yet was also followed by a response learned in acquisition training. This fact provides a common denominator with the runway experiments discussed earlier in this chapter inasmuch as shock during runway extinction training
was contingent on running from the start box into the runway, a response learned in acquisition training, and yet was also followed by running into the goal box, again a response learned in acquisition training.

A shuttlebox experiment with rats failed to find any facilitatory effect of shock during extinction training of avoidance (Kamin, 1959). During the prior acquisition training, shock followed S+ by 10 sec. whenever a rat would fail to shuttle, and extinction training was begun following 11 consecutive avoidance responses. Rn decreased across groups receiving, in respective order, no shock during extinction training, and shock delayed 40, 30, 20, 10, or 0 sec. after shuttling during extinction training.

One shuttlebox experiment with rats differed from the foregoing experiments in that the rats did not shuttle between compartments but instead were placed in one compartment on every trial and were removed after jumping the barrier between the compartments (Imada, 1959). Both compartments were virtually identical in appearance. All the rats were initially trained to avoid shock with a single procedure. During subsequent extinction training, G. 1 received no shock, and Gs. 2 through 6 were administered respectively greater shock intensities upon jumping the intercompartmental barrier. These intensities straddled the shock intensity in acquisition. Rn decreased across Gs. 1, 6, 5, 4, 3, and 2 in that order. Relatively to response speed in acquisition training, response speed in extinction training decreased across Gs. 6, 5, 1, 4, 3, and 2 in that order. The greater changes in shock intensity
thus seemed to have a relatively greater facilitatory effect in extinction training, in contrast to certain results (Beecroft, Bouska, & Fisher, 1967; Gwinn, 1949) described in the preceding section.

IB-5.6. Inescapable Feedback Stimuli

The foregoing shuttlebox experiments lend no support to the "avoidance and escape" model inasmuch as shock contingent on the trained response was inescapable during extinction training and yet facilitated performance of that response at the same time. The following experiment indicates rather conclusively that a stimulus need not be escapable during extinction training in order to serve as a feedback stimulus in a runway. In acquisition training, rats in Gs. 10 and 20 were trained to escape respectively a buzzer or a shock by running to the goal box of a straight runway apparatus (Melvin & Martin, 1966). During extinction training, neither the buzzer nor shock was presented to G. 01. However, for Gs. 02 and 03, respectively a buzzer or a shock was turned on for .3 sec. immediately as a rat would enter the runway from the start box.

During extinction training, response speed and Rn were both lowest for Gs. 01 and 12. These measures were higher for G. 22, still higher for G. 23, and highest for G. 13. Only for G. 13 did response speed during extinction training exceed response speed at the end of acquisition training.

In summary, an interaction was obtained indicating that performance during extinction training was enhanced if the stimulus,
the shock or the buzzer, was changed from acquisition training to extinction training. The present experiment also showed that runway response speed during extinction training was enhanced when a fixed-duration stimulus, and thus an inescapable stimulus, was contingent on the trained response. This effect clarifies the effects shown in the runway experiments discussed previously in this chapter, in which response speed was enhanced with a fixed-location rather than a fixed-duration stimulus: Since a fixed-duration stimulus is by definition not a drive, the present experiment demonstrated that a stimulus need not be a drive in order to serve, apparently, as a feedback stimulus. Other experiments besides those discussed herein have demonstrated apparent feedback-stimulus effects of shock in extinction training of avoidance (e.g., see Brown, 1969) and of escape (e.g., Melvin & Bender, 1968).

IB-5.7. Secondary Rewards

As will be discussed in Ss. IB-11.5 and IB-11.6, a stimulus may become capable of serving as a drive, i.e., of eliciting escape, if its presentation is followed by presentation of shock. The following experiment incorporated such a procedure: In Ph. 1 rats were subjected to a procedure in which a buzzer preceded in-escapable shock in the goal box (Melvin & Stenmark, 1968). In Ph. 2 the rats were trained to escape from the buzzer. The final phase, Ph. 3, was not an extinction phase as in the other experiments described in this chapter, since the buzzer was presented in
Ph. 3 as in Ph. 2.

In Ph. 3 rats in two separate groups were shocked respectively in the middle section of the runway or in the far section adjacent to the goal box. Response speed increased for both groups in Ph. 3 and increased more for the group shocked in the middle section. An additional group not shocked in Ph. 3 showed no increase in response speed during this phase.

In this experiment shock was presented in conjunction with incentive (buzzer) termination and was therefore not a feedback stimulus by the definition of feedback stimulus. Yet shock in the final phase served as a reward as in the other experiments described in this chapter. Thus, in view of the fact that shock typically functions as a punishment (e.g., cf. S. IB-1.3), the following generality seems to emerge: A given stimulus can become more rewarding or less punishing if presented contingently on occurrence of a response for which a performance enhancement constituting learning has been supported by some incentive other than the given stimulus. Such a given stimulus will be called a secondary reward (see also S. IB-10.7).

The experiments cited throughout this chapter generally failed to incorporate control groups for whom the incentive contingency of initial acquisition training was not in effect. Admittedly it is reasonable to assume that Rn would be zero or that shock would serve as a punishment for such control groups, as was explicitly assumed in S. IB-5.1. However, such control groups should still have been run to verify this assumption until it be-
came well enough established so that control groups would be trivial. Given this assumption, the experimental results described in this chapter indicate, typically, that interactions would have been obtained between the incentive of acquisition training and the response-contingent stimulus introduced in extinction training and as such would have established the latter stimulus, usually shock, as a feedback stimulus. In the unlikely event that the aforesaid assumption turned out to be faulty, i.e., if shock turned out to be a reward for control groups without the incentive contingency of acquisition training, it would be of interest to reconcile this finding with the contrary findings discussed earlier in S. IB-1.3.

In summary, the experiments described in this chapter present a plethora of results that are interesting but were controlled somewhat inadequately, are mutually unintegrated to some extent, and are contradictory in some details. More effort should be addressed to these problems. Reconciling the contradictory findings, for example, would clarify the boundary conditions for the described effects and would involve, first, making educated guesses as to what parameters varying between experiments might account for the contradictory results, and, second, varying such parameters as treatment variables crossed in a factorial design with the treatment variables of the original experiments. Unfortunately, investigators in the area have shown little inclination to do this but instead seem to be content with making suggestions (e.g., cf. Brown, Martin, & Morrow, 1964) without attempting any forthright
empirical proof of their validity.
Chapter 6

UNCONDITIONED STIMULI

IB-6.1. Anticipation

If a UR has followed a US, the associated CS+ often will come to elicit the same response, which is then an anticipatory CR by definition. Anticipation was first investigated by Pavlov (1927), who used food as a US, which elicited salivation as a UR in dogs. He showed, among many other things, that a ticking metronome could serve as an anticipatory CS+ for salivation. He was also able to use electric shock as a CS+ for salivation when he gradually increased shock intensity with each presentation (cf. Ss. IB-5.1, IB-8.6, IB-8.8, and IB-13.4). In addition, Pavlov used morphine as a US to condition anticipatory nausea and salivation to the experimenter's touch, the CS+ signalling morphine.

Although visual food presentation elicited a salivous UR without prior anthropogenic conditioning, this effect might have represented natural conditioning with visual food itself serving as a CS+ in relation to subsequent (e.g., gustatory) stimuli associated with food. In line with this reasoning, salivation in dogs was conditioned to a CS+, a black square, in association with a US, a ticking metronome, that had formerly served as a CS+ and had thereby come to elicit salivation (Provlov, reported in Pavlov, 1927). Higher order conditioning was thus demonstrated (see also Razran, 1955).

Anticipatory salivation is relatively greater when relatively
more food is given as a US (Gantt, 1938, also reported in Hull, 1943), and the rate of anticipatory salivation is directly related to the ongoing magnitude of hunger within individual animals (Finch, 1938; Zener & McCurdy, 1939). Anticipation has been observed for many responses besides salivation. A few examples are as follows.

Anticipatory body temperature in trainmen was observed to vary according to whether they were about to enter a familiar cold or warm station or cold freight car (see Bykov, 1957). Blood flow to the muscles increases in a runner about to start a race (Ruscher, 1965). Anticipatory limb flexion was observed in an experiment in which the US was stimulation of the motor cortex (Doty & Giurgea, 1961). In the same experiment, incidentally, this stimulation was shown not to be a reward. In another experiment septal stimulation in rats did not serve to reward bar pressing but produced a UR that was conditioned to a CS+ (Malmo, 1965). A UR evoked by cerebellar stimulation was also conditioned to a CS+ (Brogden & Gantt, 1937).

In an experiment possibly demonstrating anticipatory running, the speed of a runway response increased across three groups of rats that were required respectively to turn around, to stay in one place, or to run forward, after each occurrence of the runway response (Adelman & Maatsch, 1955). In a related experiment rats in separate groups were shocked on their front or hind paws while running for food reward (Fowler & Miller, 1963). The rats shocked on their hind paws ran forward when shocked, whereas the rats...
shocked on their front paws retreated when shocked. Response speed was measured while the rats were running toward the shock and became greater for the rats shocked on their hind paws. It should be noted that such anticipatory effects may have contributed to the feedback effect of shock in the experiments considered in the preceding chapter. However, there is no evidence bearing directly on the issue.

IB-6.2. Anticipation Conditioning as a Darwinian Process

The very fact that anticipation occurs raises a question in relation to the earlier discussion in S. IB-2.1, where it was maintained that learning evaluated between incentive training groups typically fails to occur for responses that are irrelevant to an incentive contingency. Yet, if a US is presented in a conditioning procedure as described previously in S. IA-6.1, learning evaluated through such a procedure is essentially equivalent operationally to learning evaluated between incentive training groups for irrelevant responses. An apparent contradiction occurs here, since learning of anticipatory responses does occur with such conditioning procedures, as illustrated in the preceding section. How can the apparent contradiction be resolved?

First of all, the discussion in S. IB-2.1 indicated that only as a general rule, not as a universal law, is learning limited to responses relevant to an incentive contingency. Therefore, since the concept of anticipation applies only for those relatively few responses elicited by the US under consideration, the supposition
remains that the US for these responses would not tend to effect learning for other responses except as an incentive for those other responses. Hence, the occurrence of anticipation represents no more than a minor qualification to the general principle that learning evaluated between incentive training groups is limited to responses that are relevant to an incentive contingency. Therefore, insofar as this general principle is essential in interpreting learning as a Darwinian process, as indicated in the earlier discussion in § IA-4.6, the fact of anticipation does not seriously embarrass this interpretation of learning from an empirical point of view. Thus, insofar that this interpretation of learning indicates a theoretically precise relationship of incentive learning to biological (as opposed to behavioral) evolution, as was indicated in § IA-4.7, the fact of anticipation does not seriously compromise this position. However, the question remains as to how anticipation itself relates theoretically to biological evolution.

A heuristic answer can be given in terms of how anticipation may relate to incentive learning and may thus relate to biological evolution on the same basis whereby incentive learning relates to biological evolution. To take anticipatory salivation as an example, extra (anticipatory) saliva in the mouth may interact with food presentation in such a way that extra saliva to wet the ingested food becomes able to support reward learning of a response, salivation, on which appearance of the reward, extra saliva, is contingent. This model could easily be tested by cannulating saliva out of the mouth for two groups, an experimental group and a
control group, for both of which food presentation would serve as a US. For the experimental group all the saliva would be cannulated back into the mouth, whereas for the control group saliva would be cannulated back into the mouth at only a basal flow rate as determined perhaps by salivary flow rate of yoked animals in a third group. The CS+ for food would thus be posited as an S+ or S- for extra saliva for the respective groups. In terms of salivation, any reliable difference between the groups would have to be due to the only factor varying between the groups—to the response-incentive (salivation-saliva) contingency for the experimental group—and would therefore indicate that extra saliva in the mouth is, by definition, an incentive under the conditions of the experiment. Hence, for the experimental group anticipatory salivation would really be a trained response under experimental conditions designed to assess the possibility.

However, negative results might be obtained, indicating that the anticipatory CR is in fact not a trained response. Moreover, even if positive results were obtained, the possibility cannot be ruled out that negative results would be obtained for another anticipatory CR. In fact, this possibility cannot even be assessed with anticipatory CR's such as blood flow whose direct consequences cannot be feasibly controlled as can the direct consequences of salivation. However, there is at least tentative heuristic worth in the model that anticipatory CR's are generally identifiable as trained responses. In particular, this model not only accounts for anticipation in consonance with a known behavioral principle, that
learning evaluated between appropriate groups typically fails to occur for responses that are irrelevant to an incentive contingency, but also this model thereby relates anticipation to biological evolution.

Anticipation may be related to incentive learning in another way besides that already indicated. Recall from Ss. IA-4.6 and IB-3.3 that appropriate initial response variation is necessary for incentive learning. Such initial variation could occur through anticipation, and therein might lie the prime reason why the capacity for anticipation has evolved. If so, anticipation might occur to a substantial extent for both groups in the hypothetical experiment described above, albeit such anticipation would not rule out the possibility of a reward effect between the groups. In fact, such a reward effect might be enhanced with initial anticipatory variation superimposed on spontaneous response variation. To take another example, if an active avoidance contingency is the same as the escape contingency when avoidance fails to take place, the initial response variation required for avoidance learning might occur as anticipation of escape. The following experiments bear on the issue.

IB-6.3. **Anticipatory Effects in Training**

In one experiment rats in Gs. 10, 20, and 30 were trained respectively to run, to turn, or to rear in order to avoid shock (Bolles, 1969, 1970). If the appropriate avoidance response failed to occur, the rats in Gs. 01, 02, and 03 could escape the ensuing
shock only by running, turning, or rearing respectively. Shock was thus a possible punishment but was not operationally a US for any of the groups inasmuch as shock was presented contingently in relation to a response requirement. However, for Gs. 11, 22, and 33, shock might have been expected to function as a US with escape as the UR and with avoidance as the anticipatory CR.

Avoidance learning, identified as improved performance, occurred for Gs. 10 and 22 alone. Thus, in itself, the avoidance contingency on turning was insufficient to produce avoidance learning for this response, since otherwise Gs. 21 and 23 would have learned. Likewise, the escape contingency on turning was not sufficient by itself to produce avoidance learning for this response, since otherwise G. 32 would have learned. Yet both contingencies together did produce such learning, in the case of G. 22. The escape contingency thus potentiated avoidance learning via the avoidance contingency for this group. Hence, considering escape as a UR for anticipatory avoidance, this group's avoidance learning represented anticipatory potentiation of incentive learning through the avoidance contingency.

However, the running, turning, and rearing responses all occurred with a frequency of 40% to 50% from the first trial and thereby prevented shock many times even without avoidance learning. Thus, the anticipatory potentiation for G. 22 apparently occurred above and beyond any facilitation of the initial responding that was essential in order for avoidance to be trained. In this respect the present findings add to the ideas of the preceding
In an experiment similar to that above, rats in Gs. 10 and 20 could avoid shock by running or jumping respectively (Mowrer & Lamarqueux, 1946). If the appropriate avoidance response failed to occur, the rats in Gs. 01 and 02 could escape the ensuing shock by running or jumping respectively. Gs. 11 and 12 learned to avoid equally well, but only G. 22 learned to avoid by jumping. For another group, 13, shock termination was not contingent on any response; i.e., the shock was inescapable, but running was learned as an avoidance response.

If anticipation conditioning might facilitate incentive learning, so too might incentive learning facilitate anticipation conditioning. Indeed, in the preceding experiments the UR shown to facilitate training was itself trained. To consider another possible example, recall the heart rate experiment discussed in S. IB-3.1 to illustrate differentiation. In this experiment, since S- presentation sometimes presaged S+ presentation, albeit by irregular and relatively long time intervals, the S- might have functioned at least partially as a CS+ in relation to the S+ as a US. Therefore, since the S+ elicited a certain change in heart rate, the observed generalization to the S- might have reflected anticipation, though the experiment was not specifically concerned with this possibility.

Of course, just because avoidance had an anticipatory component in the two experiments described earlier in this section, it does not follow that avoidance always reflects anticipation. In
fact, on operational grounds avoidance cannot be considered anticipation when the avoidance response does not duplicate a UR. In the preceding experiments such might appear to have been the case for those animals who learned avoidance by running when running was not an escape-trained UR. However, this conclusion must be tempered with the possibility that untrained and unconditioned running could have occurred in response to shock. Nevertheless, such behavior does not necessarily account totally for avoidance learning, as the results of the following experiment emphasize.

IB-6.4. Training vs. Conditioning of Avoidance

In the following experiment the procedure was similar to that for G. 13 in the preceding experiment with rats in respect that no escape was possible. Guinea pigs in G. 1 could avoid shock by running in a running wheel following presentation of a tone, whereas for guinea pigs in G. 2, avoidance following the tone was not possible (Brogden, Lipman, & Culler, 1938; repeated by Sheffield, 1948). The tone was thus an S+ for G. 1 but a CS+ for G. 2. For both groups response frequency was measured as the proportion of trials on which the response required for G. 1 occurred.

For G. 1 response frequency progressively increased before levelling off and was greater than for G. 2. Thus, avoidance by running was not purely anticipatory but was enhanced due to the training contingency per se. In fact, although response frequency for G. 2 increased at first, it later decreased, though not to its initial level. At the same time, however, this experiment like
those in the preceding section did not show that active avoidance by running can be acquired without any conditioning.

In fact, the results of another experiment were essentially opposite to those just described. In this experiment, humans in G. 1 could blink to avoid shock applied close to the eye, whereas shock applied in the same way was unavoidable for G. 2 (Logan, 1951). There were no other procedural differences between the groups. Frequency of blinking was measured in the same way as was response frequency in the preceding experiment. Blinking frequency was found to be greater for G. 2 than for G. 1.

To interpret this result the S+ for G. 1 can be regarded as having functioned as a CS+ though being an S+ operationally. Then, as the investigator noted, this stimulus was partially a CS+ and partially a CS- for G. 1, since it sometimes predicted shock and sometimes did not. For G. 2, on the other hand, this stimulus was a CS+ only. Thus, if the observed blinking response be regarded as purely anticipatory, G. 2 would have been expected to show superior learning as was the case. To summarize this and the preceding section, it appears that anticipation conditioning may sometimes facilitate training and may sometimes even be sufficient to account for learning of a trained response as in the experiment just described.

IB-6.5. Avoidance of Escapable vs. Inescapable Shock

The results of the following experiment confirm the results of the first experiment described in the preceding section but add
a new twist. Shock when presented followed a .5 sec. white noise by an equal time interval for all the groups in this experiment (Bolles, Stokes, & Younger, 1966, Expt. 4). The shock was unavoidable for G. 10, for whom the white noise was therefore a CS+, whereas the rats in G. 20 could avoid the shock by running in a running wheel. The white noise was therefore an S+ for the rats in G. 20. The shock was inescapable for G. 01, whereas the rats in G. 02 could escape the shock by running in the wheel. Performance was measured as the percentage of running responses that resulted in avoidance or would have done so had an avoidance contingency been in effect between CS+ presentation and shock presentation.

The main effect of the avoidance contingency (G. 20 vs. G. 10) was positive, confirming the results first described in the preceding section. The main effect of the escape contingency was also positive, indicating anticipation. However, a negative interaction was obtained, indicating interference between anticipation and incentive learning. In fact, performance was lower for G. 22 than for G. 21.

At first this finding might seem inconsistent with the findings that were described in S. IB-6.3, but the apparent inconsistency can possibly be resolved as follows. In the present experiment the shock may have been of shorter duration for G. 22 than for G. 21, since shock was escapable for G. 22 but not for G. 21. Therefore, since active avoidance generally increases parametrically with the duration of shock (see S. IB-1.3), G. 21 might have been expected to show superior avoidance as the case was. This in-
interpretation is only tentative, since the duration of shock was brief for G. 21 and was not reported for G. 22. In any case, shock was escapable for all the groups in the experiments described in s. IB-6.3, albeit not always through the response that resulted in avoidance. Thus, the duration of shock might not have been an effective parameter in these experiments as it possibly was in the present experiment.

The following experiment produced results opposite to those above in that an escape contingency facilitated avoidance. In this experiment a shuttle response by rats served as the avoidance and the escape response (Bolles, Stokes, & Younger, 1966, Expt. 1). The shock avoidance and shock escape contingencies were the same for Gs. 010, 020, 001, and 002 as for Gs. 10, 20, 01, and 02 respectively in the preceding experiment.

For G. 100 a white noise serving as S+ or CS+ was terminated when shock occurred or would have occurred failing avoidance. For G. 200 the white noise was terminated at that same time unless a shuttle response occurred, in which case this response resulted in immediate termination of the noise. The noise was thus to be assessed as a drive-incentive. Performance was evaluated as the percentage of shuttle responses that resulted in shock avoidance or in termination of the noise, or that would have done so with either of these contingencies in effect.

Positive main effects were obtained for all three factors. Also obtained was a positive interaction between the two escape-contingency factors, those for the shock and for the noise. In ad-
dition, a negative triple interaction was obtained, reflecting the result that no one contingency alone supported learning, but that all combinations of contingencies did support learning, and that the effects of a second and third contingency together were essentially additive. Thus, in this experiment anticipation conditioning with a trained UR not only did not impair avoidance as in the preceding experiment but was actually necessary for avoidance learning in the case of G. 100.

However, in the following experiment anticipation conditioning with a trained UR had no effect on trained avoidance. The procedure was exactly the same as that just described, except that the criterion response was a running response in a running wheel (Bolles, Stokes, & Younger, 1966, Expt. 2). In the present case the only findings were positive main effects of the contingency factors for avoidance and for escape from the noise. Thus, in view of the absence of any interaction involving the avoidance contingency and the escape contingency for shock, anticipation conditioning with a trained UR was not necessary for avoidance learning. To summarize this section, an escape contingency involving a given response may impair, not affect, or facilitate avoidance via the same response.
Chapter 7

CONDITIONED STIMULI

IB-7.1. Differentiation

Differentiation between a CS+ and a CS− can occur as between an S+ and an S−. Pavlov (1927) first demonstrated differentiation in his investigations of anticipatory salivation in dogs. In his basic procedure for showing differentiation, food serving as a US always followed a CS+ and never followed a CS− directly, and anticipatory salivation occurred differentially to the CS+.

With this procedure, which is typical for showing differentiation, the CS+ and the CS− were each presented in an equivalent manner rather than, for example, in assymetrical temporal relation to one another. In addition, Pavlov (1927) used another procedure, whereby the CS+ not only signalled food on some trials but also signalled CS− presentation on the remaining trials without food. Anticipatory salivation then became differentially greater to the CS+.

The unqualified word "differentiation" is usually taken to mean phasic differentiation as opposed to tonic differentiation, shown in the following experiment with dogs. In this experiment conditioning trials in one room were interspersed with conditioning trials in another room (Struchkov, cited by Asratyan, 1961). In one room anticipatory salivation was conditioned to a buzzer as a CS+, and anticipatory leg flexion was conditioned to a tactile CS+. In the other room, in which each of these CS+'s was paired
with the opposite US, the same dogs were conditioned to salivate in response to the tactile CS+ and to flex a leg in response to the buzzer as a CS+. The two rooms thus served as tonic CS's between which tonic differentiation occurred.

7.2. **Generalization and Discrimination**

Generalization and discrimination occur for CS's as for cues. As far as generalization is concerned, many experiments could be cited (e.g., see Razran, 1949), but a few examples will suffice for present purposes. One of the early findings was Pavlov's (1927) observation that an anticipatory response conditioned to an auditory CS+ occurred when a person entered the laboratory. Generalization was first investigated systematically in Pavlov's (1927) salivation experiments with dogs. Among other things Pavlov (reported in Razran, 1949) found that generalization of a salivary CR increased with increasingly prolonged training.

The following experiment illustrates a generalization gradient of conditioning. A galvanic skin response was the CR and the UR to shock, the US (Bass & Hull, 1934; cf. Grant & Dittmer, 1940). The CS+ signalling the shock was a vibration at a "zero point" on the skin. The location of this point varied among the subjects during conditioning. For each subject conditioning trials were interspersed with test trials on which the vibration was applied to this and other points, including other subjects' zero points, and did not signal shock. On the average, the amplitude of the anticipatory CR was found to follow a descending generali-
zation gradient as the point of application became farther from any given subject's zero point. When a tactile stimulus is applied to a point bilaterally symmetrical to its point of application as a CS+, the generalization gradient reverses (Anrep, 1923).

Both generalization and discrimination were shown in the following experiment. The US was an airpuff to an eye, the CR and the UR were each a blink, and the CS+ and the CS- were lights in adjacent windows (Hilgard, Campbell, & Sears, 1938). The amplitude of the anticipatory CR was measured as the proportion of CS's eliciting the CR.

During Ph. 1, only the CS+ was presented, and the amplitude of the CR increased toward an asymptote as conditioning progressed. During Ph. 2 both the CS+ and the CS- were presented. Initially in Ph. 2 the amplitude of the CR did not differ between these stimuli. Generalization thus occurred from the CS+ to the CS-. As Ph. 2 progressed, however, discrimination occurred: While the CR to the CS+ remained essentially constant in amplitude, the CR to the CS- progressively decreased in amplitude from session to session.

IB-7.3. Inhibition and Induction

Generalization decrements may occur for CS's as for cues. As was indicated in S. IB-3.2, generalization decrements imply generalization gradients, and vice versa. Hence, generalization decrements were, in effect, discussed in the preceding section.

The generalization decrements discussed there were of the
"phasic" variety. However, just as tonic differentiation can occur, as was discussed in S. IB-7.1, so can tonic generalization decrements occur. That is, if the stimulus conditions that have consistently accompanied a CS are altered, learned responding to the CS is diminished just as if the CS itself had been altered and even though the stimulus conditions that are altered affect neither the UR nor the CR aside from the effect of the change per se.

Tonic generalization decrements were first observed by Pavlov (1927), who referred to them as external inhibition. What Pavlov found, specifically, was that presentation of a novel stimulus decreased anticipatory salivation in response to a CS+ and increased salivation to a CS− in dogs. With regard to the CS−, such an increase in salivation represents external inhibition of discrimination.

The fact of external inhibition suggests that tonic learning may generally accompany phasic learning, perhaps in training as well as conditioning. What might be considered purely tonic learning occurs if the externally inhibitory stimulus is repeatedly presented with a CS+ and a CS−. Under these conditions anticipatory responding and discrimination recover, as Pavlov (1927) observed.

If a CS+ and a CS− are presented together after a standard differentiation conditioning procedure, the amplitude of the elicited CR is less than the amplitude of the CR to the CS+ alone. This effect as well as the more familiar manifestations of differentiation have been called internal inhibition. "Internal inhibi-
tion" as well as "positive induction" and "negative induction" are terms coined by Pavlov, and the phenomena were first demonstrated in his experiments on anticipatory salivation in dogs. **Positive induction** is the exaggerated amplitude of a CR to a CS+ following a few interpolated CS− presentations. **Negative induction** is the exaggerated discrimination of (failure to respond to) a CS− following a few interpolated presentations of the CS+. Pavlov (1927) observed an effect analogous to positive induction when presentation of a CS+ was omitted for a few US presentations. With the next presentation of the CS+, anticipatory salivation by dogs was enhanced.

**IB-7.4. Trace and Temporal CS+'s**

Presentation of a US would follow termination of a trace CS+ by some time interval, as was noted in S. IA-6.2. Usually such an interval is only a few seconds, and anticipatory responding may antecede termination of a trace CS+. The timing of anticipatory responding may reflect temporal discrimination. From certain findings Pavlov (1927) viewed temporal discrimination as follows, though the present terminology is somewhat different from Pavlov's.

If the parametric time from CS+ onset to US onset is relatively long, then the initial interval following CS+ onset is a negative temporal CS, "CT−," because appearance of the US does not shortly follow this interval but follows the subsequent interval "CT+." Just as discrimination of the ordinary CS− may develop,
generalized conditioned responding to a CT- should diminish as conditioning progresses. In other words, temporal discrimination should take place. This conclusion accords with Pavlov's (1927) observation that anticipatory salivation by dogs occurred progressively later after CS+ onset as conditioning progressed.

In one of Pavlov's (1927) experiments, food was presented to dogs at regular intervals. Then, when one presentation of food was omitted, salivation occurred about when it would have occurred had the food been presented. Analogous findings have been obtained for other responses including EEG arousal, galvanic skin responses, and heart rate, but not for finger withdrawal and startle responses (see Groves & Thompson, 1970).
Chapter 8

HABITUATORY STIMULI

IB-8.1. Habituation and Sensitization

A response occurring specifically to novel stimuli is called an orienting response. Some examples of orienting responses are EEG desynchronization, galvanic skin responses, changes in heart rate, and body and eye movements occurring in response to novel stimuli specifically. When a habituatory stimulus such as a light, a noise, or a shock is presented at regular intervals and elicits a habituatory response—in particular, a startle response or an orienting response or a reflex—the following observations can typically be made (Groves & Thompson, 1970; Thompson & Spencer, 1966).

At relatively low parametric intensities of the stimulus, response amplitude (for example, the amplitude of a muscle twitch) becomes progressively less with each presentation of the stimulus, and this effect is inversely related to the parametric intensity of the stimulus. As an extrapolation of this inverse relationship, response amplitude initially increases with each stimulus presentation at relatively high parametric intensities. Therefore, since initial response amplitude is directly related to stimulus intensity (cf. S. IA-6.5), the progressive decrease in response amplitude constitutes habituation, and the progressive increase in response amplitude constitutes sensitization.

As the number of stimulus presentations increases, response
amplitude follows a negative exponential course in the case of habituation. In the case of sensitization, on the other hand, response amplitude after increasing levels off gradually and then decreases, following a negative exponential course. Still, however, the final asymptotic level of response amplitude is relatively higher with relatively greater parametric intensities of the stimulus. In typical habituation experiments the habituatory stimulus is presented at parametric intervals ranging from seconds to minutes. As the parametric frequency of stimulus presentation increases, habituation becomes more pronounced for a given number of stimulus presentations, whereas sensitization first increases, then levels off, and finally decreases.

As indicated previously in S. IA-6.5, conditioning of habituatory responses may be regarded as a special case of anticipation conditioning. Therefore, insofar as anticipation conditioning be regarded as a Darwinian process as already discussed in S. IB-6.2, conditioning of habituatory responses may be regarded as a Darwinian process. Habituation has been observed for a variety of responses other than those noted above (see Thompson & Spencer, 1966), but those already noted have probably been investigated most frequently in experiments on habituation.

IB-8.2. Generalization and Dishabituation

Habituatory stimuli are analogous to cues and ordinary CS's insofar as response amplitude is measured following stimulus onset. Thus, just as learning may carry over or generalize from a
cue or CS to another stimulus (see Ss. IB-3.2 and IB-7.2), so may habituation to one stimulus generalize to other stimuli (see Thompson & Spencer, 1966; see also Montgomery, 1953). Generalization of habituation can occur, for example, between different tones. Correspondingly, a generalization decrement in habituation may occur if the habituatory stimulus is changed. For example, when a habituatory auditory stimulus presented to humans is decreased in loudness, response amplitude recovers, or, in other words, habituation is lost (Sokolov, 1960; Voronin & Sokolov, 1960).

The results of the following experiment show an interesting generalization effect. The habituatory stimulus was a tone, and response amplitude was measured for startle responses in rats (Davis & Wagner, 1969). Initially in habituation conditioning, the intensity (loudness) of the tone was relatively low for G. 1, medium for G. 2, and high for G. 3.

As habituation conditioning progressed, the intensity of the tone was gradually increased for G. 1 but remained at a constant level for Gs. 2 and 3. Finally, at the end of the conditioning procedure, stimulus intensity for G. 1 was nearly at the same level as for G. 3. Amplitude of the startle response was then determined for all three groups using the stimulus intensity that had been used all along for G. 3. Response amplitude was measured as the mean number of startle responses for each group.

G. 1 would have been expected to show the greatest habituation since habituation is most marked at lowest stimulus intensi-
ties, as mentioned in the preceding section. The important finding, however, was the degree to which habituation generalized to the high intensity of the stimulus for G. 1. Specifically, test amplitude of the startle response was greatest for G. 2 and least for G. 1. Generalized habituation was thus greater for G. 1 than was nongeneralized habituation for G. 3, which had been exposed to the test intensity of the stimulus all along. This effect was called the **incremental stimulus intensity effect** and was replicated in an experiment in which the habituatory stimulus was shock and response amplitude was measured for the hindlimb flexion reflex of acute spinal cats (Groves & Thompson, 1970).

The amplitude of a habituated response may recover if a novel stimulus is presented even if this stimulus does not itself elicit that response or is presented between the trials with the habituatory stimulus (see Thompson & Spencer, 1966; Groves & Thompson, 1970). Such recovery is analogous to external inhibition for a CS- (cf. S. IB-7.3) and is called **dishabituation**. Dishabituation decays strictly as a function of time, independently of whether or not the habituatory stimulus is presented during the decay period (Thompson & Spencer, 1966; Groves & Thompson, 1970).

**IB-8.3. Trace and Temporal Effects**

If habituation conditioning is temporarily discontinued, **spontaneous recovery** of response amplitude may occur when habituation conditioning is resumed (see Thompson & Spencer, 1966). In fact, after a single presentation of a habituatory stimulus was
omitted in one experiment, response amplitude recovered with the next presentation of the stimulus (Sokolov, 1963). Spontaneous recovery is actually a decrement in habituation, and such a decrement would appear to be a generalization decrement along the time interval between stimulus presentations. Spontaneous recovery can thus be described as a temporal trace effect somewhat akin to the effect of intertrial intervals as temporal trace cues. Such cue effects were considered in S. IB-4.4.

With repeated habituation-recovery sessions, progressively less spontaneous recovery occurs from session to session (see Thompson & Spencer, 1966). Depending on specific conditions the time required for spontaneous recovery may vary greatly: It may be 10 min. or, for startle responses in rats, over 24 hours. Spontaneous recovery time increases as habituation conditioning is increasingly prolonged beyond the time when the amplitude of the habituated response stabilizes at or above zero. This effect is known as the below-zero effect.

S. IB-8.1 indicated that habituation is a result of repeated stimulus presentations at regular intervals, and the discussion above indicated that spontaneous recovery decreases over repeated habituation-recovery sessions. Hence, response amplitude following current stimulus presentation is apparently related directly to the novelty of stimulus presentation at a given parametric time interval since previous stimulus presentation. Thus, stimulus presentation at irregular intervals would probably result eventually in habituation for any interval within the range of varia-
Therefore constant (regular) intervals between stimulus presentations are probably unnecessary as far as the development or maintenance of habituation is concerned. In fact, varying the intervals between stimulus presentations has been found to produce only a transient loss of habituation (Sokolov, 1963; Voronin & Sokolov, 1960).

The discussion in Ss. IA-6.5 and IA-8.1 indicated that habituation becomes parametrically greater as parametric response amplitude to the habituatory stimulus decreases. However, this inverse relationship reaches a limit when the lower asymptotic limit (e.g., zero) of response amplitude constrains response amplitude from decreasing (habituating) more than if initial response amplitude were higher. Under these limiting conditions the inverse relationship still holds if habituation is measured in terms of parametric spontaneous recovery time rather than as a decrease in response amplitude after habituation conditioning (see Thompson & Spencer, 1966). Thus, as initial response amplitude parametrically approaches its base level, spontaneous recovery time and hence the degree of habituation perhaps approach infinity.

As indicated above, response amplitude following current stimulus presentation is directly related to the novelty of stimulus presentation at a given parametric time interval since previous stimulus presentation. Is the same true for response amplitude following current stimulus omission or nonpresentation? The results of the following experiment indicate that the answer may be yes, though the investigated response was operationally an or-
dinary UR rather than a habituatory response.

This response was the galvanic skin response (Badia & Defran, 1970). Each human in Gs. 1 and 2 was given an equal number of trials in Ph. 1. For G. 1 certain trials in Ph. 1 consisted of presentation of a tone and then of a light. These trials were interspersed with the remaining Ph. 1 trials, on which presentation of the tone was omitted; the light was presented, however. For G. 2 the tone was presented before the light on all the trials of Ph. 1.

The procedure in Ph. 2 was a continuation of the procedure in Ph. 1 except that the tone or the light was omitted on certain trials for each subject in Ph. 2. When presentation of the light was omitted, response amplitude recovered at the time at which the light would have been presented. Thus, response amplitude following current stimulus omission was apparently related directly to the novelty of stimulus omission at a given parametric time interval following previous stimulus presentation.

When presentation of the tone was omitted, response amplitude recovered more for G. 2 than for G. 1 at the time at which the light was presented. Thus, with omission of the tone in Ph. 2, recovery from habituation was less for the group for whom the tone had been omitted in the previous phase. This effect seems analogous to the loss of spontaneous recovery with repeated habituation-recovery sessions, because in both cases recovery is apparently related directly to the novelty of the parametric time intervals between stimulus presentations.
IB-8.4. **Extinction in Conditioning**

Extinction procedures may involve repeated presentations of a former S+ or CS+ without presentation of the incentive or US and may thus be procedurally comparable to habituation conditioning. Aside from the fact that extinction follows acquisition, extinction of anticipatory responses does not appear to differ in any essential way from habituation. Thus, similarly to habituation, extinction of anticipatory CR's follows a negative exponential course, is relatively more pronounced with relatively less intense or more frequently presented CS's, can generalize, recovers after abating following presentation of a novel stimulus, can recede through spontaneous recovery, recedes less upon iterance of the extinction-recovery sequence, and can show a below-zero effect (see Thompson & Spencer, 1966).

Sensitization during extinction conditioning was shown in an experiment in which the anticipatory CR was an increase in blood pressure in dogs (Napalkov, 1963). Only one acquisition trial was given, and the amplitude of the CR increased dramatically over the extinction trials. After extinction a former CS+ like a CS- impairs response amplitude to a current CS+ when presented simultaneously with the current CS+ (Pavlov, 1927) (cf. S. IB-7.3).

The results of the following experiment indicate that anticipation may be impaired when a procedure comparable to an extinction procedure precedes acquisition. In this experiment anticipatory leg flexion in goats was conditioned with shock as a US (Lubow, 1965). When the CS+ was repeatedly presented without the
us before the start of acquisition conditioning, subsequent acqui-
sition of this response was impaired. (See Bolles & Petrinovich,
1954, for an analogous result.)

IB-8.5. Contrast

In terms of logical possibilities, adaptation can occur for
incentive learning as well as for habituatory responses, as was
noted in S. IA-6.6. Various experiments discussed later in this
chapter and in S. IB-9.4 have indeed demonstrated either adapta-
tion of incentive learning or closely related effects. The fol-
lowing experiment, while not demonstrating adaptation, does pro-
vide some background that will eventually lead into a discussion
of adaptation of incentive learning.

Rats were trained to run down a runway for food (Karsh,
1963). In both Phs. 1 and 2, a rat would be shocked when it
touched the food. In Ph. 1 the rats in G. 10 received 120 v.
shock, while the rats in G. 20 received 200 v. shock. In Ph. 2,
the rats in G. 01 received 120 v. shock, and the rats in G. 02 re-
ceived 200 v. shock. Runway response speed in Ph. 2 was greatest
for G. 11 and was least for G. 22. Also, response speed in Ph. 2
was slightly higher for G. 12 than for G. 21.

The foregoing results can be summarized as follows, in terms
of main effects: Performance in Ph. 2 was greater with 120 v.
shock in Ph. 1 than with 200 v. shock in Ph. 1 and was also great-
er with 120 v. shock in Ph. 2 than with 200 v. shock in Ph. 2.
The performance differences observed in Ph. 2 can thus be de-
scribed simply as reflecting both punishment learning carried over from Ph. 1, and punishment learning based on ongoing conditions in Ph. 2. In essence, these performance differences indicate ordinary incentive learning.

The foregoing results provide a background for the following hypothetical experiment, which will serve as a convenient point of reference in subsequently discussing some actual results. In this hypothetical experiment occurrence of the target response results in punishment—shock, say—for Gs. 2, 3, and 4 in both Phs. 1 and 2. Shock intensity in Ph. 1 is lower for G. 3 than for G. 4 and is lower for G. 2 than for G. 3. By extension, the animals in G. 1 receive no shock but are otherwise treated identically to those in the other groups. In Ph. 2 the procedure—in particular, shock intensity—for all four groups is the same as that for G. 3 in Ph. 1. Throughout both phases a reward contingency supports the target response so that shock does not obliterate performance and thereby obscure group differences through a floor effect.

The postulated results of the experiment are as follows. Performance in Ph. 2 is greater for G. 2 than for G. 3 and is greater for G. 3 than for G. 4. These particular results indicate learning carried over from Ph. 1 and accord with the empirical findings described above. By extension, it might be expected that performance would be greatest of all for G. 1 in the hypothetical experiment, but contrary to expectation performance for G. 1 is intermediate between the performance levels for Gs. 3 and 4. Shock thus becomes less punishing for Gs. 2 and 3 than for G. 1.
Therefore, from the definition of "secondary reward" in S. IB-5.7, shock is a secondary reward for Gs. 2 and 3 (cf. S. IB-10.7).

Performance for G. 1 thus reflects a contrast effect. That is, in Ph. 2 incentive learning—punishment learning in this particular case—is enhanced for G. 1 relatively to Gs. 2 and 3 since the procedure for G. 1 involves a greater shift or "contrast" between incentive magnitude in Ph. 1 and incentive magnitude in Ph. 2. In the present example incentive magnitude in Ph. 1 is, of course, zero for G. 1.

Note that a shift in incentive magnitude occurs for G. 2 as well as for G. 1, but a contrast effect occurs only for G. 1. Therefore, given that the magnitude of the shift is greater for G. 1 than for G. 2, the implication is that a contrast effect can be expected only with a relatively large shift in incentive magnitude. Hence, with a relatively small shift, incentive learning carried over from Ph. 1 apparently masks any contrast effect and thus results in an opposite effect. Empirical examples of contrast effects will be given in the next section and in Ss. IB-8.8, IB-12.1, IB-13.4, and IB-13.5 (see also S. IIA-8.6).

IB-8.6. Examples of Contrast Effects

No single real experiment has employed all four of the groups discussed in reference to the foregoing hypothetical experiment. The postulated results thus summarize and integrate a variety of real results that are consistent with the postulated results, although the procedures yielding the actual results involved minor
modifications from the hypothetical procedure described above. To elucidate the similarities between the hypothetical experiment and the real experiments discussed in this and the next sections, the groups and phases in the real experiments will be numerically denominated so as to correspond to those in the hypothetical experiment.

The following experiment used procedures equivalent to those described above for Gs. 1 and 2, except that shock was varied along a proportion-of-trials dimension rather than an intensity dimension. In this experiment rats were trained to run down a runway for food (Banks, 1966). In Ph. 1 the rats in G. 1 were not shocked, and the rats in G. 2 were shocked on 50% of the trials in an irregular sequence. The contingency for food reward was the same in Ph. 1 as in Ph. 2, and in both phases shock when given was typically administered after a rat would touch the food. In Ph. 2, when each rat in each group was shocked on every trial, runway response speed was considerably greater for G. 2 than for G. 1. This effect is an example of a contrast effect of the sort indicated in the preceding section.

In addition to the modification indicated above, certain experimental procedures have involved another modification of the procedure of the hypothetical experiment: Instead of being at a constant intermediate intensity in Ph. 1, punishment for G. 2 is gradually increased toward its final level (cf. S. IB-8.2). Still, however, punishment in Ph. 1 has an average intensity greater than zero but less than its intensity in Ph. 2, as in the
hypothetical experiment, and this procedure of gradually increasing punishment intensity yields results consistent with those postulated for the hypothetical experiment.

In one experiment, for example, an air blast that had been gradually increased was found to be an ineffective punishment for bar pressing by cats for food (Masserman, 1943). Yet an air blast that was not gradually increased disrupted bar pressing so well in other cats that these cats starved. Similar results for shock will be considered in Ss. IB-8.8 and IB-13.4. An experiment (Karsh, 1966) that will be brought up in S. IB-12.1 also demonstrated a punishment contrast effect with a procedure analogous to the hypothetical procedure of the preceding section, but with a modification other than those two indicated above.

IB-8.7. Adaptation of Passive Avoidance

To return to the hypothetical experiment discussed earlier in this chapter (S. IA-8.5), suppose that the procedure for this experiment is changed in one way, namely, that shock is not response-contingent in Ph. 1 while still being response-contingent in Ph. 2. Shock in Ph. 1 is then a habituatory stimulus rather than a punishment. In this case, from the earlier discussion in S. IA-6.6, it follows that the procedures for Gs. 1 and 3 correspond respectively to the control and experimental procedures for demonstrating adaptation of incentive learning.

Suppose that the hypothetical experiment thus modified yields the results already postulated for this experiment in S. IB-8.5.
In particular, suppose that performance is greater for G. 3 than for G. 1. Adaptation of incentive learning can then be said to occur in the experiment (cf. S. IA-6.6). The following experiments incorporated the procedural modification indicated above; i.e., shock was a habituatory stimulus in Ph. 1. In discussing these experiments phases and groups will be enumerated as indicated in the preceding section.

In Ph. 1 of one experiment, G. 3 of mice was shocked outside the lever-pressing apparatus to be used in Ph. 2 (Baron & Antonitis, 1961). G. 1 was treated identically to G. 3 except that G. 1 received no shock during Ph. 1. In Ph. 2 shock contingent on lever pressing suppressed that response for both groups, but when this punishment was subsequently discontinued for both groups, extinction of punishment learning was greater for G. 3 than for G. 1. That is, shock in Ph. 1 enhanced lever pressing rate after discontinuation of shock punishment in Ph. 2. However, shock in Ph. 1 had an opposite effect between additional groups that received no shock after Ph. 1 but were otherwise treated identically to Gs. 1 and 3. Concerning the groups that received punishment in Ph. 2, the present results are consistent with the assumed results of the hypothetical experiment, with the minor qualification that the observed performance difference between these groups occurred during extinction rather than acquisition training in Ph. 2 of the present experiment. The foregoing results thus indicate an adaptation-like effect.

Like the foregoing experiment the following series of three
experiments produced results consistent with those postulated for
the hypothetical experiment. In these three experiments habitua-
tion conditioning took place inside the apparatus (Raymond, 1968).
The procedure thus differed from that in the above experiment.
Throughout each of the three experiments, lever pressing by rats
yielded a fixed amount of food reward, and training without shock
preceded Ph. 1 in each experiment.

In Ph. 1 of Expt. 1, G. 1 was given no shock, whereas G. 2
was given 110 v. shock on a VI schedule and independently of re-
sponding. Lever pressing was slightly depressed for G. 2 in Ph.
1. In a phase between Phs. 1 and 2, neither group received shock,
and lever pressing rate became about equal between the groups. In
Ph. 2 both groups received 145 v. shock contingently on lever
pressing. The rate of lever pressing was unaffected for G. 2 but
was almost totally suppressed for G. 1.

In Expt. 2 the procedure differed from that above only in re-
spect that the experimental group, in this case G. 4 rather than
G. 2, received 220 v. shock (rather than 110 v. shock) in Ph. 1,
and in Ph. 2 both G. 1 (different from G. 1 above) and G. 4 re-
ceived 110 v. shock contingent on lever pressing. In Ph. 2 lever
pressing was not suppressed for G. 1 but was almost totally sup-
pressed for G. 4. Expt. 3 resembled the first two experiments,
but two groups received shock in Ph. 1. These groups were both
subjected to a single procedure in Ph. 1 but received 110 and 180
v. shock respectively in Ph. 2. Likewise, among control rats re-
ceiving no shock in Ph. 1, half received 110 v. shock and the oth-
er half received 180 v. shock in Ph. 2. Between the 110 v. groups, lever pressing rate in Ph. 2 was lower after shock in Ph. 1 than after no shock in Ph. 1. Between the 180 v. groups, on the other hand, lever pressing rate in Ph. 2 was higher after shock in Ph. 1 than after no shock in Ph. 1. As would be expected, the rate of lever pressing averaged lower for the 180 v. groups than for the 110 v. groups in Ph. 2.

From S. IA-6.6 recall that habituation of incentive learning would be evaluated with a procedure quite different from those described above. In particular, to demonstrate such habituation, incentive magnitude would have to be varied among groups in each phase, whereas the procedures described above did not differ between the relevant groups in Ph. 2. The foregoing experiments thus provide no information regarding habituation. The habituation procedure for incentive learning was described primarily so that this point would be clear, and apparently there are no results directly concerning habituation of incentive learning. The foregoing experiments pertain only to passive avoidance; adaptation of active avoidance and of escape will be considered in S. IB-9.4 (cf. S. IB-10.7).

IB-8.8. Adaptation vs. Contrast

The preceding section dealt with adaptation-related effects on passive avoidance, and the section before that dealt with contrast effects on passive avoidance. To integrate the material in those two sections, it should be noted by way of summary that such
adaptation-related effects differ from such contrast effects in two ways.

1. The distinction between adaptation and contrast involves a difference in emphasis: The term "adaptation" refers to performance for G. 3 in comparison to G. 1, whereas the term "contrast" refers to performance for G. 1 in comparison to G. 3.

2. The term "adaptation" implies habituation conditioning in Ph. 1, whereas the term "contrast effect" implies incentive training in Ph. 1. In the pertinent experiments discussed in this chapter, such incentive training took place inside the apparatus to be used in Ph. 2, but the experiments discussed in the preceding section demonstrated adaptation-related effects when habituation conditioning in Ph. 1 took place either inside or outside the apparatus to be used in Ph. 2.

The following experiment provided a comparison between habituation conditioning outside the training apparatus and incentive training inside the apparatus in Ph. 1. For G. 2a of rats, lever pressing for food produced shock, and the duration of this shock—i.e., shock magnitude along a duration dimension—was gradually increased to the duration at which shock was initially introduced for G. 1 (Church, 1969) (cf. S. IB-8.6). Except for the gradual increase in the duration of the shock, the procedure was the same for G. 1 as for G. 2a. G. 2b received the same treatment as did G. 2a except that the gradual increase in shock duration occurred outside the lever apparatus for G. 2b. Then, when all three groups were given equal-duration shocks contingently on lever
pressing for food reward, the rate of lever pressing was suppressed more for G. 1 than for G. 2b and more for G. 2b than for G. 2a. Analogous differences among groups were obtained in a runway experiment to be described in S. IB-13.4.

In the lever-pressing experiment just described, the observed performance difference between Gs. 2a and 2b might have been due to either or both of the following circumstances.

1. Whereas shock constituted a punishment for G. 2a, shock constituted a habituatory stimulus for G. 2b while the shock was increasing in duration.

2. When shock became a punishment for G. 2b, the location of the shock changed for this group but did not change for G. 2a. This change amounted to a change in the stimuli accompanying the shock and might thus have been expected to produce some degree of "disadaptation" analogous to dishabituation of habituatory responses (cf. S. IB-8.2). Accordingly, after the change, performance suppression by shock might have been expected to be greater for G. 2b than for G. 2a, as the case was.
As was noted in S. IA-6.7, a single stimulus may serve as an incentive in relation to an S+ and as a US in relation to a CS+, with the S+ and the CS+ being separate stimuli. Suppose that such has been the case for an individual animal and that the CS+ is then presented in the training environment. Typically the CS+ will now elicit the response trained to the S+, even though this response has not been trained to the CS+.

For example, in Ph. 1 of an experiment with dogs, a bar press yielded food reward whenever the bar was pressed at least 2 min. after the last bar press (Shapiro & Miller, 1965). For discussion purposes the S+ and the S- will be assumed to have been the temporal cues T+ and T-. By this assumption T- was the 2 min. following a response, and T+ was the time between the end of T- and occurrence of the next response.

In Ph. 2 food as a US was presented immediately after a tone serving as a CS+. In Ph. 3 the training conditions of Ph. 1 were reinstated except that in addition the CS+ was sometimes presented. CS+ presentation in Ph. 3 produced earlier responding than would otherwise have been likely. The CS+ thus elicited the same response that T+ elicited.

In Ph. 1 of an experiment with rats, food immediately was presented after termination of a CS+, a 60-sec. tone (Estes,
In Ph. 2 bar pressing was trained on an FI-4 schedule of food reward. Ph. 3 differed procedurally from Ph. 2 only in respect that food reward was no longer given, and the rate of bar pressing declined accordingly. In Ph. 4, during which reward still was not given, presentation of the CS+ elicited bar pressing.

In another experiment bar pressing by rats was trained on an FI-4 schedule of food reward (Trapold, Carlson, & Myers, 1965). In another phase a US consisting of food followed CS+ presentation after a fixed or variable time interval for Gs. 1 and 2 respectively. Thus, G. 1 alone received temporal differentiation conditioning (cf. S. IB-7.4). In the final phase the CS+ was presented at the beginning of the fixed nonreward interval, and FI scalloping was facilitated for G. 1 but not for G. 2. The various results considered above pertain to "hope" conditioning, and the results described in the next two sections indicate fear conditioning. In connection with the earlier discussion in S. IB-3.3, it should be noted that the effects discussed in this and the following sections could possibly contribute to Darwinian response variation at the start of a new training regimen, "new" insofar as a former CS+ serves as a new cue.

IB-9.2. Punishment as a US

CS+'s signalling demonstrated punishments have been used in more experiments than have CS+'s signalling demonstrated rewards as in the preceding experiments. In most of these experiments
with punishment, the avoidance response to the S+ was shuttling, and performance was evaluated as response speed measured from the onset of the S+. In one such experiment a shuttle response was trained in Ph. 1 for G. 1 of dogs and consisted of jumping a barrier in a shuttlebox (Leaf, 1964). The punishment was shock.

presentation of the S+ consisted of dimming the lights. For G. 1 conditioning in Ph. 2 took place in another room, while the animals were curarized. A tone serving as a CS+ was consistently paired with shock, the US. The CS- was a tone different from the CS+.

The procedure for G. 2 was the same as that for G. 1 except that the training and conditioning phases were in reverse sequence; i.e., conditioning preceded training for G. 2. In Ph. 3 the procedure for both groups was the same as the previous training procedure except that the CS+ and the CS- were sometimes presented. For both groups the CS+ produced higher performance than did the CS-, though CS- presentation did elicit jumping. An important aspect of this experiment was that three days intervened between Phs. 1 and 2 for G. 2. With sufficiently shorter times—for example, one day—animals cannot be trained in Ph. 2, as discussed later in S. IB-9.4.

In another experiment the procedures for two groups of dogs were essentially the same as in the preceding experiment (Overmier & Leaf, 1965). In this experiment S+ presentation consisted of turning off a light, and the CS+ and the CS- were tones. For the animals given conditioning before training, responding to the
CS+ occurred from the outset of Ph. 3 but did not continue throughout Ph. 3, whereas for the animals first given training, responding to the CS+ not only occurred from the outset of Ph. 3 but also continued throughout Ph. 3 and was faster than for the other group.

In the majority of experiments involving conditioning and training with punishment, training preceded conditioning. In what is perhaps the prototype experiment, panel pressing by dogs was trained as a shock-avoidance response in Ph. 1, with a light serving as the S+ (Solomon & Turner, 1962). In Ph. 2 the animals were curarized, the CS+ and the CS- were tones, and the US was shock. Conditioning took place in the training apparatus used in Ph. 1, as in most experiments with punishments as US's. In Ph. 3 presentation of either the S+ or the CS+ elicited panel pressing.

In one experiment lever pressing by monkeys was trained on a Sidman avoidance schedule, and a series of clicks was followed by unavoidable shock (Sidman, Herrnstein, & Conrad, 1957). The rate of lever pressing increased during presentation of the clicks. In an experiment with shock as a drive rather than as a punishment, rats were trained to escape the shock by going from a white to a black compartment in Ph. 1 (May, 1948). In Ph. 2 the rats were restrained, and a buzzer was sounded simultaneously with shock. In Ph. 3 the buzzer alone elicited escape.

IB-9.3. **Differentiation in Fear Conditioning**

Certain findings considered in the preceding section illus-
trated differentiation in that performance differed between responses to a CS+ and to a CS−. The following experiment extends these findings as they relate to differentiation. Dogs were trained to shuttle seven times per minute in Ph. 1 (Rescorla & LoLordo, 1965). In Ph. 2 fear conditioning was carried out with tones serving as CS+ and CS−. Shock served as the punishment in Ph. 1 and as the US in Ph. 2. In Ph. 3 CS+ presentation tripled the jumping rate of the animals, whereas CS− presentation reduced the jumping rate almost to zero.

These animals received differentiation conditioning with the usual type of procedure, but for additional animals differentiation conditioning in Ph. 2 took place with a different procedure, whereby half of the trials consisted of CS+ presentation followed by CS− presentation with no shock. The other half consisted of CS+ presentation followed by shock. In Ph. 3 CS+ presentation doubled the jumping rate, whereas CS− presentation reduced the jumping rate almost to zero for this group as for the other group. Recall from S. IB-7.1 that Pavlov obtained analogous results for anticipatory salivation with a procedure analogous to the present procedure whereby a CS− rather than the US was sometimes presented after the CS+.

In another experiment dogs were trained to avoid shock by shuttling at regular intervals in Ph. 1 (Moscovitch & LoLordo, 1968). In Ph. 2 the animals were penned in and shocked on one side of the shuttlebox. The onset of the shock occurred 1 sec. before or 1 or 15 sec. after offset of a tone, the CS, for Gs. 1,
2, and 3 respectively. For G. 1 CS presentation in Ph. 3 produced a slight decrease in jumping rate, but CS offset produced a marked decrease in jumping rate. For Gs. 2 and 3, CS onset produced a substantial decrease in jumping rate. Thus, in effect, CS onset or offset per se served as "CS-" depending on whether a shock-free period had followed CS onset or offset in Ph. 2.

In another experiment dogs were trained to jump in a shuttle-box to avoid shock when the S+ was presented in Ph. 1 (Overmier, 1966). Fear conditioning in Ph. 2 took place inside or outside of the shuttlebox. Two tones serving as CS+'s signalled .5 and 50 sec. shock respectively. In Ph. 3 latency of jumping was shorter in response to the CS+ that had signalled 50 sec. shock than to the CS+ that had signalled .5 sec. shock.

Temporal differentiation of fear was shown in the following experiment. In Ph. 1 dogs were trained to avoid shock by shuttling at regular intervals (Rescorla, 1967a). In Ph. 2 a 30-sec. tone served as a CS+ signalling shock. In Ph. 3 the rate of jumping decreased at the onset of the tone and then increased with the duration of the tone. Finally, 30 sec. after onset of the tone, the rate of jumping was double the baseline rate.

In an experiment on extinction of fear, avoidance at regular intervals was trained (LoLordo, 1967), and a CS+ elicited the avoidance response in the same manner as CS+'s elicited trained responses in the other experiments that have been discussed in this chapter. However, the present experiment differed from these experiments in respect that the incentive, shock, and the US, a
loud noise, differed from each other in the present experiment. Perhaps for this reason presentation of a CS− did not diminish avoidance responding in this experiment. As for extinction, the present experiment showed that avoidance performance to the CS+ increased as acquisition conditioning progressed and decreased as extinction conditioning progressed.

IB-9.4. Adaptation of Active Avoidance

When the subject of fear conditioning was introduced in S. IB-9.2, it was briefly noted that dogs sometimes cannot be trained if conditioning precedes training. This effect is shown in the following experiment. G. 1 of dogs was given preliminary conditioning 24 hours before Ph. 1 (Seligman & Maier, 1967). They were conditioned in a shuttlebox with a procedure in which offset of a CS+ and of the US, shock, were not contingent of jumping.

In Ph. 1 the animals in Gs. 1 and 2 could press a panel to turn off shock. (All the groups in this experiment were not run concurrently.) The dogs in G. 3, a yoked group, received shock with G. 2 but could not turn off the shock. G. 4 received no shock but was otherwise treated like G. 3.

In Ph. 1 the dogs in G. 2 learned to press the panel to escape the shock, but the dogs in G. 1 generally failed to learn. In Ph. 2, 24 hours after Ph. 1, avoidance of shock was trained in a shuttlebox. Most of the dogs in Gs. 2 and 4 learned to avoid, whereas the majority of dogs in Gs. 1 and 3 failed to learn.

It appears that CS+ presentation in preliminary training was
irrelevant to the results of the experiment. Thus, in comparing performance between Gs. 1 and 2 in Ph. 1, adaptation of escape appears to have occurred for G. 1 in the manner described earlier in S. IA-6.6. Likewise, in comparing performance between Gs. 3 and 4 in Ph. 2, adaptation of active avoidance is evident. Since G. 2 unlike G. 3 did learn to avoid the shock, this adaptation was related to the prior absence of an escape contingency for G. 3.

Does such adaptation fulfill the definition of habituation (cf. Ss. IA-6.6 and IB-8.7)? Apparently no results are available to answer the question. However, it has been noted that avoidance can be trained three days (see S. IB-9.2) but not one day (see above) after conditioning. Apparently, then, the capacity for avoidance can undergo spontaneous recovery analogous to spontaneous recovery of habituatory responses after habituation (cf. S. IB-8.3). Such recovery was directly shown for avoidance in an experiment in which separate groups of dogs were trained one, two, three, or six days after conditioning with shock as the US (Overmier & Seligman, 1967): Avoidance was impaired only after one intervening day.

In the following experiment, which extends the analogy between such adaptation and habituation, spontaneous recovery of avoidance was precluded with a procedure analogous to that whereby spontaneous recovery after habituation can be prevented with repeated habituation-conditioning sessions (cf. S. IB-8.3). One day after conditioning with shock, dogs underwent a training procedure in a shuttlebox and as usual did not learn to avoid or to escape
(Seligman, Maier, & Geer, 1968). This session thus amounted to an additional habituation conditioning session with inescapable shock. The dogs still failed to learn in another session seven days after this training, a considerably longer time interval than was required for spontaneous recovery in the preceding experiments. Recovery also did not occur in subsequent tests in the next four weeks. Slow recovery finally did occur, however, when the dogs were dragged with a leash across the shuttlebox and were thus exposed to the escape contingency. In summary, the above experiments indicate that adaptation of active avoidance is at least somewhat analogous to habituation of habituatory responses.
Chapter 10

CONDITIONED REWARDS

IB-10.1. Conditioned and Unconditioned Rewards

Conditioned rewards as such have been found to support incentive learning in many experiments (e.g., see Kelleher & Gollub, 1962; Meyers, 1958; Miller, 1951; Wike, 1966). The following experiment is illustrative. In Ph. 1 all the rats in the experiment were trained to press a bar for food (Melching, 1954). In Ph. 2 bar pressing continued to yield food for all the rats. The procedure for G. 10 was the same in Ph. 2 as in Ph. 1, whereas the procedure in Ph. 2 differed for G. 20 in respect that a buzzer sounded each time a rat in this group would press the bar for food.

In Ph. 3 a bar press would no longer yield food, and for G. 02, but not for G. 01, the buzzer sounded each time a rat would press the bar. The buzzer was thus intended as a conditioned reward for G. 22. The other groups were control groups.

The rate of bar pressing was greater for G. 22 than for G. 21 in Ph. 3, indicating that the buzzer was a reward after having been paired with presentation of food. However, bar pressing rate in Ph. 3 was less for G. 12 than for G. 11, indicating that the buzzer was a punishment in the absence of prior conditioning. The rate of bar pressing did not differ between Gs. 21 and 11 in Ph. 3, indicating that previous buzzer presentation per se did not influence ongoing performance. However, bar pressing rate in Ph. 3
was greater for G. 22 than for G. 12, indicating that the buzzer became relatively more rewarding after pairing of the buzzer with food presentation. The buzzer therefore served as a presumptive conditioned reward for G. 22—presumptive because of the prima facie nature of the evidence: The experiment did not incorporate control groups lacking presentation of the presumptive US, food, in Ph. 2 (cf. Ss. IA-6.1 and 6.2) and thus did not actually demonstrate that the buzzer-food pairing per se was essential to the observed results. In other words, the possibility was not ruled out that previous buzzer presentation per se was the essential factor, and that the observed conditioning effect represented pure sensitization of incentive learning (cf. S. IA-6.6).

Suppose that one incentive is presented consistently before another incentive upon fulfillment of a single response requirement for both incentives. The second incentive might then function as an unconditioned incentive, even though it is not a US operationally. In fact, even if the two incentives are presented simultaneously, their aftereffects could, heuristically speaking, be related in the manner of a CS+ to a US. If conditioning were thus to occur, the two incentives would interact rather than having additive effects. Such conditioning might account for incentive-incentive interactions of the kind previously mentioned under Item 8 in S. IB-2.4.

IB-10.2. Differentiation in Conditioning of Rewards

The following experiment on conditioned rewards showed dif-
ferentiation with a balanced design (cf. Ss. IA-5.2 and IA-6.2). For each rat in this experiment, intragastric feeding followed ingestion of one substance, whereas intragastric injection of water followed ingestion of another substance (Holman, 1969). The two substances were balanced among the rats. Subsequently they preferred the substance that had preceded intragastric feeding over the other substance, and more of the substance was ingested that had been followed by intragastric feeding.

In each session of a somewhat similar experiment, thiamin-deficient rats in G. 1 were given a thiamin injection, the US, after ingestion of saccharin (Garcia et al., 1967). Between sessions, while these rats were becoming deficient again, they were allowed access to water but not to saccharin. The rats in G. 2 were given water when those in G. 1 were given saccharin, and vice versa. The two groups were otherwise treated identically to each other. Subsequently, saccharin intake was greater for G. 1 than for G. 2 when the rats in both groups were given saccharin while thiamin-deficient. Similar results with thiamin-deficient rats were obtained in another experiment (Zahorik & Maier, 1969). Generalization has been demonstrated in relation to conditioned rewards in a number of experiments (e. g., see Wike, 1966).

The above findings suggest that food reward, probably the most commonly used experimental reward, is rewarding at least partly because the associated gustatory stimuli serve as conditioned rewards signalling the normal physiological events subsequent to ingestion. That such events may be directly rewarding
without ingestion was shown in an experiment in which panel pressing by rats was greater with intragastric milk injection contingent on panel pressing than with intragastric saline contingent on panel pressing (Kahn, 1951). An additional finding of this experiment sheds some additional light: Panel pressing was greater when milk for drinking was contingent on panel pressing than when milk or saline was contingently injected into the stomach. Similarly, in another experiment with rats, choice performance in a T-maze was learned faster with a reward consisting of milk for drinking than with a reward consisting of intragastric milk injection (Miller & Kessen, 1952).

If a tentative conclusion can be drawn from all the above experiments, it is this: Certain "internal" stimuli (e.g., thiamin injection, intragastric injection of milk) can support reward learning and can additionally function as US's in conditioning gustatory stimuli as conditioned rewards. Once conditioned, these gustatory stimuli do not merely replace their aftereffects in rewarding ingestion but serve as rewards above and beyond the rewarding aftereffects.

IB-10.3. **Extinction of Conditioning of Rewards**

Suppose that ingestion is not inborn behavior but reflects reward learning as does lever pressing, etc. Then, if gustatory rewards are conditioned rewards, as indicated above, rather than ultimate rewards, ingestion learned through such rewards would be expected to undergo extinction if the aftereffects of ingestion
were precluded from serving as US's. Therefore, since precluding these aftereffects would mean that they would be unavailable as rewards as well as US's, ingestion, if it is learned behavior, would be expected to undergo complete extinction. Extinction of eating was, in fact, shown in an experiment with a single dog with an esophageal fistula (Hull et al., 1951), although before extinction occurred the dog ate about 3/4 of its body weight in food per feeding session.

On the assumption that a saccharin stimulus would not signal nutritive aftereffects, reward learning with saccharin might be expected to undergo extinction without any special procedures. Choice learning supported by saccharin reward was indeed found to undergo spontaneous extinction for rats trained in a T-maze (Smith & Capretta, 1956); the degree of extinction was a direct function of hunger magnitude at the time of consumption. This relationship with hunger was interpreted in view of prior observations suggesting that saccharin facilitates sugar absorption in mice: Such an effect might be rewarding, thus counteracting extinction, and would be relatively more likely at relatively lower levels of hunger. In the present experiment not only T-maze performance but also ingestion of saccharin was extinguished in that the rats took progressively more time to consume a fixed volume of saccharin solution. Extinction of ingestion increased with hunger magnitude as did extinction of choice performance.

During training in another experiment, a food pellet would be given to a rat, and shortly thereafter a bar would be presented
that the rat could press for an additional pellet (Nagaty, 1951). Control procedures established that only the second pellet supported learning of bar pressing. However, extinction of bar pressing occurred at the same rate regardless of whether delivery of the first or second pellet was discontinued. Therefore, given that various aftereffects of eating the first pellet must have occurred only after the second pellet was eaten, these aftereffects apparently had become conditioned to the second pellet and had thereby enhanced reward learning supported by the second pellet. Withdrawal of the first pellet would thus have resulted in some extinction of conditioning and consequently of this reward learning.

IB-10.4. Conditioned Rewards, Hunger, and Homeostasis

Hunger facilitates incentive learning with food reward, as was discussed in S. IB-1.4. Since this is a parametric effect, a mechanism for this effect might be as follows: Hunger facilitates conditioning with food as a conditioned reward, and food thereby becomes more effective as a reward than it would be with a lower magnitude of hunger. The following experiments demonstrate such facilitatory effects on incentive conditioning.

In one experiment rats in Gs. 1 and 2 were given respectively grape juice and milk when hungry and were given respectively milk and grape juice when not hungry (Revusky, 1967). When subsequently given a choice between grape juice and milk, the rats in G. 1 preferred grape juice, whereas the rats in G. 2 preferred milk.
Similarly, after rats had been given a solute while they were thirsty, they preferred this solute to another consumed while not thirsty (Revusky, 1968b).

In another experiment rats were forced to one arm of a T-maze when hungry and to the other arm when not hungry (Kurz & Jarka, 1968). The same weight of food reward was available at the end of each arm. On free-choice trials choice performance averaged higher toward the side on which the rats had been fed while hungry. On 50% of these trials the rats were as hungry as on the trials when they were forced to this side, and the rats were not hungry on the remaining free-choice trials as on the remaining forced-choice trials. In view of the present finding, food apparently became a conditioned reward in conjunction with its surroundings, and hunger apparently facilitated conditioning of this total CS+, food plus surroundings.

In summary, hunger drive appears to facilitate reward conditioning of CS+'s signalling US's associated with ingestion. Such facilitation may be long-lasting, as shown in the following experiment. Infant rats were allowed to eat only when starved, and learning through food reward was faster for these rats in adulthood than for control rats not starved in infancy (Renner, 1967). Furthermore, electric shock that deterred the control rats did not deter the previously starved rats from performing the learned response.

Apparently, then, if any extinction of food-reward conditioning occurred at all for the starvation group, it was insufficient
to reduce reward learning to the level for the control group. This lack of extinction is not necessarily as enigmatic as it might seem, since hunger may have functioned as a tonic CS in initial conditioning (cf. Ss. IB-7.1 and IB-7.3). If so, extinction learning like learning in general could not have been expected to generalize completely along a stimulus gradient, a hunger gradient in this case, and would thus have remained incomplete under the normal adulthood conditions of nonhunger (cf. S. IB-12.4).

In summary, the experiments considered in this and the two preceding sections indicate that routine, homeostatic ingestion may at least partially reflect incentive learning with conditioned rewards. Perhaps conditioned rewards direct routine homeostasis likewise through other types of behavior that are amenable to incentive learning—for example, cardiovascular activity, renal and intestinal functioning, etc. (e.g., cf. Ss. IB-2.1 and IB-3.1). It is tempting to speculate that the more proximate candidates for unconditioned rewards are in turn conditioned themselves (cf. S. IB-6.1), ultimately to US's consisting of stimulation of the central nervous system, notably the limbic reward sites. Homeostasis may thus depend largely on incentive learning supported by a chain of conditioning. Such a homeostatic system would epitomize a system having evolutionary survival value, since incentive learning, as a Darwinian process, has the flexibility to redirect or to re-adjust homeostatic processes largely as the need arises (e.g. cf. Ss. IA-4.6 and IB-2.1). The capacity for incentive learning thus has obvious survival value in relation to such a system.
IB-10.5. **Information as Reward**

In the following experiment, an apparatus similar to a T-maze was used (Prokasy, 1956). After turning left or right, rats were restrained in a "delay chamber" for 30 sec. After this delay the rats received food on 50% of the trials in an irregular sequence and independently of left-right choice performance.

For each rat the delay chamber on one side was consistently black or white, in balanced fashion among the rats, before food presentation and was always the opposite albedo on the trials with no food. On the other side the delay chamber was white on 50% of the trials and black on the remaining 50% in an irregular sequence. On this side the albedo of the delay chamber was uncorrelated with food presentation.

The rats developed preferences for the delay chamber in which the albedo of the chamber was correlated with presentation of food as a US. On this side the albedo CS+ and CS- in combination were thus more rewarding than were the same albedo stimuli on the other side, where each albedo was a partial CS+ and an equally partial CS-. In other words, "information" was a reward relatively to "no information."

In experiments similar to the foregoing, choice performance to the informational side was found to increase with the weight of food given (Mitchell, Perkins, & Perkins, 1965) and with the magnitude of hunger (Wehling & Prokasy, 1962). Choice performance was found to be greater to where informative CS's were presented immediately after occurrence of the requisite response than to
where presentation of equally informative CS's was delayed after occurrence of the requisite response (Mitchell et al., 1965). In this and the above experiments, the US was food. In another experiment information was preferred over no information when water was given instead of food (Levis & Perkins, 1965).

IB-10.6. The Shock-right Paradigm

Several experiments with rats have shown that electric shock may become rewarding if the shock is a response-contingent CS+ signalling presentation of food. The basic methodology for these experiments was as follows. The apparatus was a T-maze with a goal box at the end of each arm. This construction is usual for T-mazes generally. When a rat would turn into either arm of the T-maze, a door prevented retracing to the other arm except as noted later. Thus, a noncorrection procedure was followed, as opposed to a correction procedure, whereby a rat can go from one arm to the other on a single trial. Noncorrection procedures are followed in most T-maze experiments.

A panel on the far wall of each goal box could be illuminated. The two panels, one per goal box, were illuminated to different degrees. From trial to trial the brighter illumination was varied from side to side in an irregular sequence.

Food reward was pitted against no food in the two goal boxes. Reward was always on the brighter side. A turn to the bright or dim side was thus designated respectively as a "correct" or "incorrect" response.
Shock when given was administered between the choice point and a goal box of the T-maze. For certain groups the correct response alone was shocked. The paradigm is thus called the "shock-right" paradigm. Except as noted otherwise, performance in the shock-right paradigm is the inverse of the mean number of incorrect responses prior to criterion learning and may thus be regarded as choice performance.

IB-10.7. **Shock Punishment as a Conditioned Reward**

A prototypic shock-right experiment is the following. The rats in Gs. 10, 20, and 30 respectively were not shocked, were shocked for correct responses, and were shocked for incorrect responses (Fowler & Wischner, 1965). The parametric illumination difference between the goal boxes was increased across Gs. 01 through 05 in that order. Parametric performance increased across Gs. 10 through 30 in that order and across Gs. 01 through 05 in that order. These relationships held among subgroups with either of the factors constant at any level, except that there was an interaction taking the form that performance was slightly lower for G. 25 than for G. 15.

In summary, for Gs. 20 and 30 combined, shock had the average effect of increasing the proportion of responses toward the side without shock. The overall effect of shock was therefore to function as a punishment. Yet performance was lower for the unshocked G. 10 than for G. 20, for whom shock was a CS+ signalling food. For G. 20, therefore, shock fulfilled the definitive criterion of
a reward. However, considering the aforesaid interaction, shock
signalling food was rewarding only when superimposed on parametric
conditions that produced relatively slow learning.

Before free-choice training commenced in the foregoing exper­
iment, all the rats had been given forced-choice pretraining with­
out shock but with food in a goal box. With the forced-choice
procedure, each rat was forced to the left-bright, left-dim,
right-bright, and right-dim sides on an equal number of trials.
The effect of this pretraining was assessed in the following ex­
periment.

The free-choice training procedure was the same for Gs. 10
and 20 in this experiment as for Gs. 15 and 25 respectively in the
preceding experiment (Bernstein, reported in Fowler & Wischner,
1969). In the present experiment the parametric number of pre­
training trials increased across Gs. 01 through 05 in that order.
For G. 03 the number of pretraining trials was the same as in the
preceding experiment, in which all the rats received an equal num­
ber of pretraining trials. G. 05 in the present experiment re­
ceived four times this many pretraining trials.

Performance was approximately the same for Gs. 13 and 23 in
the present experiment as for Gs. 15 and 25 in the preceding ex­
periment. In the present experiment free-choice performance de­
creased across Gs. 01 through 05 in that order, but the number of
pretraining trials did not interact with shock conditions. Thus,
for example, Gs. 15 and 25 in the present experiment both per­
formed at about the same level as did G. 14 in the preceding ex­
periment. In summary, neither food nor the illumination stimuli were permitted to support incentive learning during pretraining, and incentive learning was increasingly impaired after increasingly extensive pretraining (cf. S. IIA-3.5). This impairment resembles adaptation of incentive learning as described earlier in S. IB-8.7.

As was indicated in S. IB-5.7, a secondary reward by definition becomes more rewarding or less punishing when presented contingently on occurrence of a response for which a performance enhancement constituting learning is supported by some incentive other than the secondary reward. From this definition a conditioned reward is a secondary reward if conditioning of the reward is simultaneous with reward training as in the shock-right paradigm. In this case the supporting incentive (reward) is the US.

Much of the material presented herein can be integrated under the concept of secondary rewards. In particular, the secondary rewards that have been discussed fall into these categories: (a) feedback stimuli of the sort discussed earlier in Ch. 5, Part IB; (b) secondary rewards associated with contrast effects as indicated previously in S. IB-8.5; (c) certain conditioned rewards as indicated above; and (d) other stimuli acting as secondary rewards through incentive-incentive interactions (e.g., cf. Ss. IB-2.3 and IB-5.7). The term "secondary reward" as defined herein does not have a meaning that is entirely consistent with common usage, since this term commonly refers only to conditioned rewards.
Factors Affecting Reward Learning through Shock

In one experiment the weight of food reward, the illumination difference between the goal boxes, and hunger magnitude were respectively greater for Gs. 2000, 0200, and 0020 than for the corresponding low treatment level groups (Hawkins, 1965). G. 0001 received no shock, whereas the rats in G. 0002 were shocked for correct responses. The main effects were all positive and were increasingly pronounced for Gs. 0002 vs. 0001, 0020 vs. 0010, 0200 vs. 0100, and 2000 vs. 1000 in that order.

Inspection of the data indicates that the six $2^2$ interactions varied inversely with the respective means of the two corresponding main effects and were all negative except that the Hunger x Shock interaction was positive. Performance facilitation by shock thus appeared to increase with increasing hunger but to decrease with an increasing weight of food reward and with an increasing illumination difference between the goal boxes, though performance was still greater with shock than without shock. Facilitation vanished as mean errors decreased parametrically to about 30.

Inspection of the data indicates that a positive Food-Reward main effect, a positive Hunger main effect, and a negative Illumination x Hunger x Shock interaction, in that order, were the most prominent effects on response speed (as opposed to the aforesaid effects on choice performance). A negative Shock main effect and a negative Illumination x Shock interaction were also prominent. Thus, whereas shock for the correct response facilitated choice performance, the same shock impaired response speed. An effect
tantamount to a stimulus-response interaction was thus evident (cf. S. IB-2.2). The negative Shock effect on response speed is in contrast to the facilitatory effect that shock contingent on a running response had on the speed of that response in the experiments that were discussed in Ch. 5, Part IB.

In another experiment G. 100 was trained with a correction procedure, whereas G. 200 was trained with the usual noncorrection procedure (Fowler, Spelt, & Wischner, 1967). G. 010 received no shock, whereas G. 020 received shock for correct responses. The illumination difference between the goal boxes was greater for G. 002 than for G. 001.

The main effects were all positive and were increasingly great for Gs. 002 vs. 001, 020 vs. 010, and 200 vs. 100 in that order. The three $2^2$ interactions varied inversely with the respective means of the two corresponding main effects and were all negative. In fact, facilitation vanished as mean errors decreased to about 30, as was the case in the preceding experiment. Thus, for G. 002 the simple main effect of shock was essentially synonymous with the Noncorrection x Shock simple interaction. In other words, within G. 002 shocking the correct response enhanced performance with the correction procedure only.

In another experiment shock was not given for G. 1 (Prince, 1956). Shock for the correct response was introduced on the first free-choice trial for G. 2 and on the 26th such trial for G. 3. Performance was greater for G. 1 than for G. 2. Shock was thus a punishment for G. 2 as it apparently was for G. 25 in the first
experiment discussed in the preceding section.

However, the number of trials to criterion did not differ between Gs. 1 and 2. Conversely, performance did not differ between Gs. 1 and 3, but G. 3 took fewer trials to reach criterion than did G. 1. Shock contingent on the correct response thus produced relatively more facilitation when shock was introduced relatively later in training. The findings of the shock-right experiments support a generality made earlier in S. IB-10.2 in reference to gustatory CS+'s: that conditioned rewards do not merely replace their US's as rewards but serve as additional rewards. It seems ironic that shock in the present experiments became rewarding through the same type of conditioning process whereby food apparently comes to serve as a reward (cf. Ss. IB-10.2 through IB-10.4).
IB-11.1. **Conditioned and Unconditioned Punishments**

Conditioned punishments as such have been found to effect learning in a number of experiments (see Campbell & Church, 1969, Appx. B for a bibliography). In the following experiment, which illustrates fear conditioning, a light served as a conditioned punishment, and shock served as an unconditioned punishment (Mowrer & Aiken, 1954). In Ph. 1 rats learned to press a bar for food. In Ph. 2, when the bar was absent, a light served as a CS+ signalling shock for an experimental group, whereas for two control groups the light and the shock were temporally juxtaposed in an opposite manner (cf. S. IA-6.2). Ph. 3 was procedurally the same as Ph. 1, and all the groups performed similarly to each other. In Ph. 4 presentation of the light was made contingent on bar pressing for all the groups, and bar pressing was considerably suppressed for the experimental group but not for the control groups. Similar results were obtained in a later experiment (Evans, 1962).

The following experiment extends these findings. In Ph. 1 bar pressing for food was trained in rats (Seligman, 1966). In Ph. 2, when the bar was withdrawn, two CS+'s signalled shock. For G. 10, onset of the CS1+, of the CS2+, and of the shock occurred in that order, and these stimuli were all terminated together. G. 20 received the same treatment except that in addition, the CS1+
was presented without the other stimuli as frequently as with the
other stimuli. The treatment for G. 30 differed from the treat-
ment for G. 10 in respect that the shock was presented in random
temporal relation to the CS+'s for G. 30, though the CS+'s were
themselves presented together as for G. 10. The CS+'s were a
flashing light and a white noise, balanced among the subjects—
balanced with respect to which CS+ was the CS₁+ and which was the
CS₂+.

In Ph. 3 presentation of the CS₁+ was contingent on bar
pressing for G. 01, and presentation of the CS₂+ was contingent on
bar pressing for G. 02. Bar pressing was suppressed for all the
groups except G. 30, and suppression was greatest for G. 11. An
earlier experiment had followed an analogous design except that a
reward rather than a punishment was conditioned in rats (see Egger
& Miller, 1962, 1963): Food rather than shock served as the US.
The results were not entirely symmetrical between these food and
shock experiments in respect that bar pressing rate in the food
experiment was about equal between Gs. 12 and 30, analogous to the
same groups in the shock experiment, when the CS+ was presented
contingently on bar pressing. Otherwise, however, symmetrical re-
results were obtained with analogous groups: Bar pressing rate in
the food experiment was greater for Gs. 11 and 20 than for G. 30,
and the rate of bar pressing was greatest for G. 11, when CS+ pre-
sentation was contingent on bar pressing.
IB-11.2. **Associability**

In various experiments on conditioned punishments, the CS+’s were gustatory as were the conditioned rewards that were discussed in Ss. IB-10.2 through IB-10.4. To summarize these experiments collectively, drinking of a solute was followed once by toxicosis, which was induced by X-irradiation or by administration of nitrogen mustard, apomorphine, physostigmine, or one of various other substances serving as US’s (see Revusky & Garcia, 1970). Subsequently, the solute, presented contingently on drinking, suppressed drinking in rats, mice, cats, or monkeys and thus acted as a conditioned punishment. In one experiment rats learned to avoid a particular solute concentration in differentiation from other concentrations of the solute (Rozin, 1969a). In another experiment rats learned to differentiate a particular water temperature as a conditioned punishment for drinking (Nachman, 1970).

In one experiment conditioning succeeded even when X-irradiation, the US, was not administered until up to 12 hours after administration of saccharin, the CS+ (Smith & Roll, 1967). In the same experiment, with sucrose as the CS+, conditioning still occurred with delays of up to 6 hours between sucrose presentation and X-irradiation. Similarly long delays were similarly effective in other experiments with gustatory CS+’s (e.g., Revusky, 1968a; Rozin, 1969a).

Effective contingencies with such long delays are unusual in behavioral experiments generally, and an obvious question is why gustatory stimuli in particular become punishing after only one
conditioning trial when so many other candidates for CS+'s must precede toxicosis during the delay period. The logical answer would seem to be that gustatory stimuli are particularly, almost uniquely, associable with US's producing toxicosis. The results of the following experiment confirm this idea.

Ph. 1 consisted of a single session (Garcia & Koelling, 1966). In Ph. 1, whenever a rat in any group would take a lick of fluid, the rat was immediately presented with an auditory, a visual, and a gustatory stimulus, namely, a click, a light flash, and saccharin in water. The rats in G. 10 received a foot shock 2 sec. after each lick. The rats in G. 20 received mild X-irradiation after the session but well before Ph. 2.

In Ph. 2 the click and flash but not the saccharin were contingent on each lick for G. 01. For G. 02 the click and flash were absent in Ph. 2, but saccharin was dissolved in the water. Neither shock nor X-irradiation was administered to any rat in Ph. 2.

Drinking in Ph. 2 was hardly suppressed for Gs. 12 and 21 but was suppressed about 80% below normal for Gs. 11 and 22. It is established that the toxicoses induced by X-irradiation decreases saccharin consumption at a later time only if saccharin consumption has preceded the toxicosis (see Revusky & Garcia, 1970). Therefore the suppression for G. 22 was presumably related to the prior intake of saccharin.

In summary, the click-flash and saccharin were effective as conditioned punishments for drinking when they signalled shock and
toxicosis respectively but not when saccharin signalled shock, and not when the click-flash signalled toxicosis. This finding was replicated in a subsequent experiment in which shock was delayed longer after licking in Ph. 1 than in the foregoing experiment (Garcia & Koelling, 1967). These findings were confirmed and extended in several experiments (see Revusky & Garcia, 1970).

It thus appears that certain CS+'s and US's are more associative with each other than with other stimuli. Such associability would seem to explain why gustatory stimuli in particular become conditioned as CS+'s when innumerable other stimuli also appear before the US. However, the issue is not all that simple, and delay following gustatory CS+'s will be discussed further in the next chapter.

IB-11.3. **Shock as an Apparent Unconditioned Reward**

In one experiment, after rats turned left or right in a T-maze, they were retained for 45 sec. in a delay chamber (Knapp, Kause, & Perkins, 1959). Having entered this chamber they were shocked therein after a time interval that varied from trial to trial. After the delay food reward was available regardless of which side had been chosen.

The shock contingency was the same for both choices. However, in one of the delay chambers, a brief stimulus preceded the shock and thus served as a CS+. This stimulus was presented in the other delay chamber at varying time intervals after a rat would enter the chamber, and here the stimulus and the shock were
not presented in fixed temporal relationship to each other. The rats developed preferences for the delay chamber with the CS+ signalling shock. Similar findings have been obtained in several other experiments concerned with choice performance by rats (see Perkins et al., 1966).

In the above experiment, since the CS+ signalling shock apparently was more rewarding than the same stimulus not signalling shock in the opposite chamber, shock would appear to have been an unconditioned reward. Yet such a conclusion is inconsistent with the findings discussed earlier, in S. IB-11.1, that shock serves an an unconditioned punishment. This apparent inconsistency may be related to the fact that shock preceded food presentation during conditioning in the above experiment. Shock may thus have become a conditioned reward as in the shock-right experiments that were discussed in Ss. IB-10.7 and IB-10.8. Shock may thereby have supported higher-order reward conditioning in the above experiment. The result of this experiment is amenable to an alternative interpretation, which is as follows.

In one chamber the CS+ was the brief signal or, more holistically, this signal in conjunction with the chamber. The other chamber may also have functioned as a CS+. As such this chamber was present for a longer time than was the signal in the other chamber, since the irregular timing of the shocks prevented temporal conditioning with the chamber as a CS+. The chamber might thereby have become relatively more punishing than the briefer CS+ on the other side of the T-maze. This reasoning does not extend
to the previously discussed findings that shock was an unconditioned punishment, since these findings were not based on a procedure whereby CS+ presentation as well as presentation of the conditioning chamber was contingent on the target response. The following experiment supports the "chamber as a CS+" interpretation in that the design of this experiment precluded higher-order conditioning.

In this experiment rats spent 11 hours per day in an apparatus in which they received unavoidable shock at irregular intervals (Perkins et al., 1966). The schedule of shock did not depend on where a rat happened to be in the apparatus. Correlation between shock intensity and location was obviated by shocking some of the rats through ear clips rather than through the grid floor.

On one side of the apparatus, a light signalled the shock, whereas on the other side, the shock signalled the light. The rats spent more time on the side on which the light signalled the shock. This time increased proportionately with the duration of light presentation and with the frequency of the shocks. When the light-shock sequence was reversed on each side of the apparatus, the rats spent more time on the side opposite to the previously preferred side.

IB-11.4. Does Avoidance Reflect Fear?

Consider the following line of reasoning. An S+ for active avoidance signals shock and therefore may function as a conditioned punishment whose behavioral effect is fear. Hence, if ter-
mination of the S+ is contingent on the avoidance response, the S+ may function as a drive whose behavioral effect, escape, may likewise be designated as fear. Such escape may account for avoidance. In other words, avoidance may reflect fear.

This reasoning has often been invoked in the literature but is untenable. Generally herein, untenable theories, and even some tenable ones, have been bypassed in order to concentrate on actual findings. However, an examination of the avoidance = fear question should be worthwhile in bringing into sharper focus some of the subject matter already discussed, and also because the avoidance = fear model has been advanced in the literature to explain fixation and will therefore have to be dealt with in that connection.

To begin with, assume momentarily that a punishment—in particular, an S+ signalling shock—will function as a drive, as the model presumes. Then conversely an S+ signalling food reward, say, should function as a forfeit. In other words, an animal should learn to respond to an S+ signalling reward so as to prevent S+ termination if possible. Therefore, if termination of such a signal is requisite for presentation of the reward, as for example when a rat leaves the start box serving as the S+ in a runway, the rat should learn to avoid receiving the reward. The argument thus reduces to absurdity. Moreover, in view of the earlier discussion in S. IB-2.5, it should be apparent that the basic assumption of the avoidance = fear model is wrong—i.e., that punishments need not function as drives.
Empirically, S+'s have supported avoidance without any corresponding increment in their capacity to serve as incentives supporting escape (see S. IB-6.5) or even avoidance (McAllister & McAllister, 1964), except for such transient effects as noted later in S. IB-11.6. Thus, if rats are trained to shuttle whenever an S+ is presented, they do not avoid the S+ (e.g., Keehn, 1959). On the contrary, they wait for the S+ before shuttling. Avoidance may thus be learned without any apparent conditioning of fear.

IB-11.5. Conditioned Drives

The present conclusion that avoidance per se does not reflect fear runs into a problem with the finding that a CS+ in fear conditioning can act as a conditioned drive, as shown in the following experiment. The CS+ was a tone and a light presented together (Brown & Jacobs, 1949). In Ph. 1 each presentation of the CS+ antecedent of an inescapable shock, the US, and continued after the shock began for G. 1 of rats. The procedure for G. 2 differed only in respect that no shock was given. The procedure for G. 3 differed from that for G. 2 in respect that the tone and the light were also not presented.

In Ph. 2 no shock was administered, but the tone and light together were presented immediately each time a rat in any group was placed in the apparatus. The tone and the light were immediately turned off when the rat jumped a hurdle. For G. 1 average latency throughout Ph. 2 was less than for Gs. 2 and 3. Prior conditioning with shock thus enhanced the effectiveness of the
tone and light as a drive. Moreover, latency for G. 1 progres-
sively decreased from trial to trial in Ph. 2, whereas latency
progressively increased for Gs. 2 and 3.

How can the findings of this experiment be reconciled with
the logical and empirical conclusion of the preceding section—the
conclusion that S+'s for active avoidance do not serve as such by
functioning as drives? For one thing, recall that temporal dif-
ferentiation can occur in training and in anticipation condition-
ing, as was noted in Ss. IB-4.3, IB-4.4, and IB-7.4. Similarly,
from various findings that were discussed in Ss. IB-9.1 and
IB-9.3, the conclusion seems warranted that temporal differentia-
tion occurs when a CS+ functionally replaces an S+ in the manner
described in those sections. That is, a CS+ functions as an S+
only during a CT+ time interval bearing the same temporal rela-
tionship to US presentation that the T+ segment of S+ presentation
has to incentive presentation. Perhaps temporal differentiation
also occurs with conditioned incentives and drives: A conditioned
incentive or drive might function as such in a training regimen
only insofar as the time since its onset exceeds the interval be-
tween onset of this CS and presentation of the US during condi-
tioning.

Yet an active avoidance response as such can occur only while
the avoidance contingency is in effect—i. e., before the time
from S+ onset exceeds the interval between S+ onset and presenta-
tion of the punishment. Therefore, insofar as temporal differen-
tiation would occur in conditioning of an avoidance S+ as a condi-
tioned drive, such an S+ cannot have a T+ interval before shock onset, i.e., while the avoidance contingency is in effect. Thus, an S+ would not act as a conditioned drive during this interval.

Therefore, although escape from a conditioned drive was, in fact, shown in the preceding experiment, this finding is a questionable basis for supposing that an S+ for avoidance facilitates avoidance by acting as a drive. But if an S+ for avoidance is not conditioned as a drive, then why was the CS+ in this experiment conditioned as a drive? In this experiment escape from the CS+ (tone and light) could occur when the time from CS+ onset exceeded the time between CS+ presentation and presentation of the US during prior conditioning. Thus, regardless of whether temporal differentiation occurred, the CS+ could have functioned as a conditioned drive. Similarly, temporal differentiation in conditioning of drives and incentives would not be incompatible with the empirical evidence that a CS+ as such can serve as a punishment, since CS+ presentation contingent on a response requirement is still contingent even if the CS+ does not become punishing until some time after its onset.

IB-11.6. **Temporal Differentiation in Drive Conditioning**

If conditioning of incentives and drives involves temporal differentiation as indicated above, such differentiation could conceivably be the outcome of temporal discrimination resembling temporal discrimination in anticipation conditioning (cf. S. IB-7.4). Thus, in conditioning of drives and incentives, the neg-
ative time-interval (CT-) between CS+ onset and US onset could have a transient effect like that of the positive time-interval (CT+) following US onset, just as an S- or a CS- temporarily acts as an S+ or a CS+ in the course of discrimination learning (cf. Ss. IB-3.5 and IB-7.2). If temporal discrimination thus occurs, the CT- segment of an avoidance S+ should acquire and then lose the property of being a conditioned punishment as avoidance training progresses. Hence, the S+ might gain and then lose some effectiveness as a punishment.

Such an effect was shown in an experiment in which an S+ for avoidance was made contingent on bar pressing for food by rats (Kamin, Brimer, & Black, 1963). As avoidance acquisition progressed, the S+ first suppressed and then failed to suppress bar pressing. This reversal of suppression might have mirrored temporal discrimination. Another interpretation is also plausible: Since avoidance as such precludes presentation of punishment, of the US of the avoidance = fear model, training of avoidance may have resulted in extinction of any conditioning that did occur; thus the reversal of suppression. The possibility of such extinction provides a further rationale, besides that of possible temporal differentiation, whereby the fact of conditioned drives can be reconciled with the fact that an S+ for avoidance produces no apparent fear (see S. IB-11.4) or only transient fear as in the foregoing experiment.

If temporal differentiation is indeed involved in conditioning of drives and incentives as indicated in the preceding sec-
tion, it might be expected that a drive could serve as a US in conditioning an accompanying stimulus as a drive, since a stimulus by accompanying a drive would have a positive time-period. Such an effect was shown in the following experiment. In Ph. 1 rats in G. 1 were given strong shock in a white compartment and were thus trained to escape to a shock-free black compartment by touching the door between the compartments and thereby activating an electric relay that opened the door (Miller & Lawrence, reported in Miller, 1951). In Ph. 2 these rats could no longer open the door in this way but were no longer shocked.

In this phase it proved possible to train them to perform a new response to escape from the white compartment. Specifically, the rats were trained to turn a wheel to open the door. In Ph. 3 they could no longer open the door by turning the wheel and were then trained to press a bar to open the door. Gs. 2 and 3 received the same treatment as did G. 1, except that parametric shock intensity for G. 2 was intermediate between that for G. 1 and that for G. 3, which received weak shock in Ph. 1. G. 2 did not learn as well as did G. 1, and G. 3 showed no escape learning at all in Phs. 2 and 3.
Chapter 12

DELAYS

IB-12.1. Descending Delay Gradients in Training

In formal training procedures the contingent stimulus is usually presented or terminated at the end of a delay interval that begins when the response requirement is met---i. e., when the required response occurs, or at the criterion point in time at which the prohibited response has failed to occur for the required length of time. When this delay interval is varied as a treatment factor, the typical finding is that incentive learning decreases parametrically with increasing delays (e. g., cf. Renner, 1964). In other words, incentive learning follows a descending delay gradient. In experiments with rats a few seconds' delay of reward or of punishment can result in an appreciable decrement in incentive learning (e. g., Church, 1969; Logan, 1952; Perin, 1943a, 1943b).

In one experiment choice learning by rats decreased parametrically with increasingly delayed food reward for the correct choice response (Logan, 1952; cf. Logan, 1965a, 1965b). Also, increasingly delayed punishment has been found to result in a decreasing frequency of avoidance in a Y-maze (Warden & Diamond, 1931), but this finding was not confirmed in a later experiment (Bevan & Dukes, 1955). Evaluated as suppression of lever pressing for food reward, rats' passive avoidance of shock is less pronounced with delayed than with immediate onset of the shock after the lever press and follows a monotonically descending delay gra-
When punishment was first discussed in S. IB-1.3, experiments were cited showing that shock punishment of parametrically increasing duration was increasingly effective in suppressing food-rewarded lever pressing. Similarly, in experiments with dogs, shuttlebox escape from shock was found to be increasingly suppressed with parametrically increasing durations of shock immediately after the escape response (Church & Solomon, 1956). That is, in different phraseology, shuttlebox learning decreased with increasingly delayed termination of shock after the escape response.

In one experiment suppression of escape diminished as electroconvulsive shock was delayed longer after escape (Coons & Miller, 1960). The investigators interpreted the suppression of escape to be passive avoidance of electroconvulsive shock. In an experiment (Kamin, 1959) already discussed in S. IB-5.5, passive avoidance decreased and Rn increased with increasingly delayed shock punishment superimposed on extinction training for active avoidance.

In the experiments discussed above, the delay interval began at the time of occurrence of various responses. However, if fulfillment of an incentive contingency is contingent on nonoccurrence of a response, the delay interval would begin at the criterion time for nonoccurrence. Therefore, insofar as this criterion time is at the end of a constant time interval from S+ onset, parametric differences in delay could be evaluated from delay in-
For rats Sidman avoidance is diminished in terms of bar pressing rate as shock presentation is increasingly delayed parametrically from the time of the previous shock or response (cf. S. IB-4.5). Delay of punishment has been measured from S+ onset for passive avoidance in certain experiments (e. g., Bixenstein, 1956). Punishment delay was measured from S+ onset in the following experiment, in which suppression of eating was demonstrated and represented passive avoidance. Rats in separate groups were shocked 3, 6, or 12 sec. after onset of a 3-sec. buzzer if and only if they ate while the buzzer was on (Mowrer & Ullman, 1945). Eating during buzzer presentation occurred with proportionately more buzzer presentations as the shock was increasingly delayed.

The experiments described so far in this section were concerned with the effects of delay variation among groups. Similar effects have been shown when the delay interval was varied as a treatment factor within groups. In particular, differentiation based on delay was shown in the following experiment.

On every other runway trial in a trace training paradigm, rats in every group received immediate food reward contingent on running to the goal box (Burt & Wike, 1963). In terms of response speed, differentiation between consecutive trials was about equal between groups for whom the contingency on alternate trials was 120 or 80 sec. of confinement in the goal box without food reward. Differentiation was less pronounced for the remaining groups, for whom the contingency on these trials was as follows in order of
decreasing differentiation: 20 sec. nonrewarded confinement, or food reward given 100, 60, or 20 sec. after entry to the goal box. The 20 sec. delay of reward produced no differentiation. In another experiment, prior delayed punishment mitigated the ongoing effect of immediate punishment (Karsh, 1966). This result indicates an effect analogous to the contrast effects that were discussed in S. IB-8.6.

IB-12.2. **Ascending Delay Gradients in Training**

In one experiment rats preferred immediate food plus shock to no food with no shock but preferred no food with no shock to delayed food plus delayed shock (Renner, 1966). Apparently, then, the food and shock gradients descended at different rates and thereby crossed, so that immediate food plus shock was a reward, whereas delayed food plus shock was a punishment. Therefore, since an incentive is "single" only on an operational basis and not by any absolute criterion, the above finding implies that a single stimulus might have opposite incentive properties depending on a delay factor. By extension, a stimulus might have no incentive properties except with delay, in which case an ascending delay gradient would be apparent. It is thus unreasonable to presume any universal "law of descending delay gradients."

In fact, the following experiment demonstrated an ascending delay gradient if shock be interpreted as a punishment. After rats turned left or right in a T-maze, they were retained for 45 sec. in a delay chamber (Knapp, Kause, & Perkins, 1959). After
the delay the rats received food reward regardless of which side they had chosen.

In one of the delay chambers, the rats were shocked immediately upon entry. The rats preferred this chamber to the other, in which shock began 30 sec. after entry. Thus, an ascending delay gradient for shock was obtained, assuming that shock was a punishment.

However, shock might instead have been a conditioned reward, as was discussed in S. IB-11.3 for another part of the same investigation. Alternatively, in view of this earlier discussion, the shock chamber might have served as a conditioned punishment in relation to delayed shock. Thus, the results of the above experiment may indicate no more than avoidance of a conditioned punishment.

IB-12.3. Delay Gradients in Conditioning of Incentives

Delay gradients for US's can be evaluated from delay intervals measured from CS+ onset, much as delay gradients in training may be evaluated from delay intervals measured from S+ onset, as was discussed in S. IB-12.1. Such US delay gradients for conditioned incentives were first investigated in experiments with food as a US. In these experiments a descending delay gradient was observed with a buzzer (Jenkins, 1950) or a light (Bersh, 1951) as a conditioned incentive for bar pressing by rats.

The delay gradients in these experiments had descended by 81 sec. (Jenkins, 1950) or 10 sec. (Bersh, 1951). However, as was
indicated in S. IB-11.2, US delay gradients with gustatory CS+'s can take hours to descend, even up to 12 hours, with US's producing toxicosis. In fact, US delay gradients with conditioned gustatory incentives may not even begin to descend until over six hours between response-contingent CS+ presentation and the single presentation of the toxic US (Revusky & Garcia, 1970).

Such flat gradients pose a question alluded to earlier, in S. IB-11.2: Why are gustatory stimuli so effective as CS+'s when so many other stimuli precede the US more closely? Based on the evidence the answer given was that gustatory stimuli are particularly associable with US's producing toxicosis.

The concept of such associability rationalizes the existence of flat delay gradients, but a problem remains: In nature more than one gustatory stimulus might precede a US. In such cases, if the US corresponds to a nutritional factor (cf. Ss. IB-10.2 and IB-10.3) or to a factor producing toxicosis, a rat's very survival may depend on learning of the correct association. But how is such an association singled out? In order to answer this question, it will be helpful to digress momentarily to consider some applicable findings.

IB-12.4. Experiments Designed by Rats

A gustatory stimulus can serve as a conditioned punishment long after an associated US producing toxicosis has been presented (see S. IB-11.2). A nutritionally deficient food may act analogously as a conditioned punishment after recovery from a deficien-
cy associated with the food. For example, one experiment showed that rats prefer a thiamin-enriched diet to a thiamin-deficient diet after recovery from the deficiency (Rozin, 1965). Similarly, another experiment showed that rats prefer diets enriched with thiamin, riboflavin, or pyridoxine after recovery from deficiencies of these vitamins (Rozin & Rodgers, 1967).

In effect, then, the deficiency per se served as an unconditioned punishment. Thus, rats on a deficient diet tend to be anorectic. Consequently, their behavior is such that only one gustatory stimulus may precede any associated US's (Rozin, 1969b).

In particular, the rats sample food in such a way that they can learn what food is associated with a needed vitamin, and once they have sampled this food, they prefer it. In effect, then, the rats design their own experiments in such a way as to remove the confounding between separate stimuli that could precede a US associated with only one of these stimuli. The rats thus single out and learn the correct association.

IB-12.5. Interference from Familiar vs. Novel Stimuli

From a logical standpoint rats might be able to single out an association between a CS and a US by less drastic means than the sampling behavior mentioned above. In particular, if a given US were to follow a novel associable stimulus as well as familiar associable stimuli, the rats would have a logical basis for learning as association between the novel stimulus and the US if the US had not previously followed the familiar stimuli. Conversely, if
more than one novel stimulus were to precede an associable US, the correct CS+ could not be singled out logically. It might thus be expected that conditioning with a novel CS+ would be impaired if another associable novel stimulus also preceded the US, whereas conditioning would be less impaired if a familiar stimulus instead of another novel stimulus preceded the US.

The results of the following experiment confirm this idea.
In Ph. 1 rats in Gs. 1000 and 2000 were given respectively decaffeinated coffee or dilute vinegar to drink for about a week (Revusky, Lavin, & Pschirrer, reported in Revusky & Garcia, 1970). Ph. 2 consisted of a single session. In Ph. 2 the rats in G. 0100 were given saccharin solution, while the rats in G. 0020 were given sucrose solution. Fifty minutes later, when the rats in G. 0012 were given nothing, each rat in G. 0020 was given either decaffeinated coffee or vinegar, whichever was the familiar substance for the particular rat. The rats in G. 0030 were conversely given the unfamiliar substance. Gs. 0021 and 0031 received no further treatment, and no G. 0011 was included in the design of the experiment. For G. 0002 toxicosis was induced with lithium chloride 100 min. after ingestion of saccharin or sucrose.

Two days later all the rats were given a choice between distilled water and saccharin or sucrose, whichever had been ingested in Ph. 2. Choice performance was evaluated as intake of the solution relative to total fluid intake and was found to be greatest for Gs. 0021 and 0031 and least for Gs. 0012 and 0022. Lithium chloride administration thus decreased proportionate saccharin and
sucrose intake, and this effect was undiminished or diminished de­
pending respectively on whether a familiar or a novel substance
had been ingested between saccharin or sucrose ingestion and ad­
ministration of lithium chloride.

IB-12.6. Familiar vs. Novel Stimuli as CS+'s

Several other experiments have produced complementary results
showing better learning with a novel CS+ than with a familiar CS+
(see Revusky & Garcia, 1970). In one experiment, for example,
rats in separate groups were irradiated or sham irradiated one
hour after having been given both grape juice and milk, one of
which was novel. The novel substance was varied between groups
arranged factorially in relation to the irradiation factor. The
two substances were presented in balanced sequence within the
factorial subgroups.

Two days later all the rats were given a choice between the
substances. Fluid intake was measured as number of licks. Com­
pared to sham irradiation, irradiation decreased intake of the
novel substance relatively to total fluid intake.

Such a familiarity vs. novelty effect was also obtained in an
anticipation conditioning experiment that was described in S.
IB-8.4. Such effects in conditioning appear to be analogous to
adaptation of incentive learning (cf. Ss. IB-8.7, IB-8.8, and
IB-9.4) because in either case a novel stimulus is more effective
than a familiar stimulus. In summary, descent of delay gradients
appears to depend on the following factors in conditioning of in­
centives: (a) associability between the CS+ and the US; (b) interference from other associable stimuli, especially novel stimuli, preceding the US; (c) sampling behavior that ameliorates such interference; and (d) possibly the familiarity vs. the novelty of the CS+ itself.
Chapter 13

LATENT CUES

13.1. Latent Learning

The following experiments demonstrate some effects quite unlike any discussed so far herein. The apparatus in one experiment was a T-maze with goal boxes that distinctly differed visually from each other and from the rest of the T-maze (Seward, 1949). The goal boxes were not visible from the choice point. During the initial procedure the goal boxes contained no food, and rats were allowed to explore the T-maze freely. Subsequently, each rat was placed directly into one of the goal boxes and was fed there. After this procedure the rats were placed in the stem of the T-maze and were observed to turn at the choice point toward the goal box in which they had been fed.

In another experiment rats initially were allowed to explore freely six adjoining compartments arranged in a row and separated by swinging doors (Strain, 1953). The compartments differed from each other in their floor coverings and in their black and white interior patterns. Stimuli exterior to the maze were carefully excluded. Following the initial procedure the rats were locked into an end compartment and were shocked there. The rats were divided into four groups, and each rat was then placed in one of the four middle compartments depending on what group the rat was in. It was found that more rats went away from than toward the compartment in which they had been shocked, and this effect was rela-
tively greater for rats placed closer to the shock compartment.

In a different experiment rats had been trained to 100% choice performance with food reward in a T-maze (Brown & Halas, 1957). Then, between consecutive trials, the rats were directly placed eight times in the formerly baited goal box now without food. On the ensuing trial some of the rats failed to turn into the arm that had had food but instead turned into the other arm. In addition, latency was lower on this trial than on the preceding trial. In other experiments a decrement in reward-trained running has likewise been observed after nonrewarded intertrial goal box placement (e.g., Kimble, 1961, pp. 320-323).

To paraphrase the three experiments described above, a CS+ or CS- such as a goal box was first made contingent on a response to a given stimulus, e.g., to the start area of a T-maze. The CS was then presented without the given stimulus or response preceding it, and in such a way that a CS- became a CS+ or vice versa. Performance to the given stimulus was subsequently altered as if the CS had become a CS+ or CS- while contingent on the response. The given stimulus thus had a latent cue (S+ or S-) effect that was brought out with conditioning that did not involve this stimulus. Such an effect is called latent learning.

IB-13.2. Latent Learning with Uninterrupted Training

Suppose that a reward contingency is introduced for a response after the training procedure in its other aspects has already been in progress. Such a procedure would differ from the
procedures of the preceding section in respect that the present procedure incorporates the conditioning process into the training regimen. With this procedure, in view of the findings mentioned in the preceding section, latent learning might be expected to be superimposed on whatever learning would have occurred without the initial training regimen minus reward.

That is, after a shift from nonreward to reward, learning should be faster than it would be at the start of a comparable procedure with reward all along. In other words, learning should be faster with a given number of preshift trials than with no preshift trials. By extension, learning might be expected to be faster with a given number of preshift trials than with fewer or no preshift trials.

Such an effect or an analogous effect has been shown not only for a nonreward-reward shift but also for the other two types of shifts, a nonpunishment-punishment shift and a reward-nonreward shift, described in the preceding section. Such effects are illustrated in various experiments to be described in this chapter. In the case of a nonreward-reward shift, such effects have been observed in a number of experiments (see Thistlethwaite, 1951), of which the following is a prototypal example.

IB-13.3. **Shifts to Reward**

Rats were given daily trials in a maze in which a turn at any choice point led in one direction to a dead end and in the other direction to another choice point or, after the last choice point,
to a goal box (Blodgett, 1929). Doors prevented retracing to previous choice points. Performance increases were measured as decreases in the daily number of turns into a dead end.

Rats in Gs. 1, 2, and 3 were given food in the goal box starting with Trials 1, 3, and 7 respectively. Measured from the first trial, a relatively slight increase in performance occurred for the rats in Gs. 2 and 3 over their nonrewarded trials, whereas performance increased considerably more for G. 1 over the concomitant trials. However, measured from the first reward trial, performance increased more per day for Gs. 2 and 3 than for G. 1, indicating latent learning.

Therefore, since performance tended to level off gradually after initially increasing, performance increased more for, say, G. 2 than for G. 1 after Trial 3. This difference may be described by saying that latent learning occurred with a nonzero shift but not with a zero shift and was therefore a direct function of the magnitude of the incentive shift. Possibly, however, the opposite relationship, an inverse relationship, might hold between a zero shift and a sufficiently small nonzero shift because of incentive learning carried over from preshift training, just as carry-over learning may mask contrast effects with sufficiently small shifts as indicated earlier in S. IB-8.5. The foregoing experiment and others discussed shortly point to a generality, that latent learning may take place with a given number of preshift trials in comparison to fewer or no preshift trials. By extension, latent learning, if it occurs, may be regarded as a direct
function of the number of preshift trials.

IB-13.4. **Shifts to Punishment**

From S. IB-8.5 recall the hypothetical experiment discussed in relation to contrast effects occurring when punishment is made contingent on a previously unpunished response. The results described below are consistent with the results postulated for the hypothetical experiment. To elucidate the similarity between the actual results and the postulated results, the following experiment will be described in such a way that the numerical group designations correspond to those in the hypothetical experiment, as was done in the latter part of Ch. 8, Part IB.

The findings of the following experiment demonstrate latent learning with a punishment shift but provide so much additional information that their interest is not at all limited to the issue of latent learning. Rats were trained to run down a runway for food (Miller, 1960). The food contingency was the same among all the rats and throughout the experiment. Ph. 1 followed pretraining with food and without shock. At the start of Ph. 1, response speed was essentially equal among all the groups of rats.

In Ph. 1 the rats in G. 1 were not shocked, whereas the rats in Gs. 2a and 3 were shocked as they picked up the food. The rats in G. 2b were shocked outside the apparatus, but not in the apparatus, in Ph. 1. The intensity of the shock was gradually increased for Gs. 2a and 2b from an initially low level to 400 v. (cf. Ss. IB-8.6 and IB-8.8), at which point Ph. 2 began. The rats
in G. 3 received 400 v. shock on every trial of Ph. 1. In Ph. 2 a single procedure was followed for all the groups: On each trial in Ph. 2, as a rat would pick up the food, it received 400 v. shock.

Response speed for Gs. 1 and 2b remained essentially constant as Ph. 1 progressed. Response speed for G. 2a progressively decreased from trial to trial in Ph. 1. For G. 3 response speed in Ph. 1 initially decreased more precipitously than for G. 2a and then, over the remaining Ph. 1 trials, stayed at an essentially constant level lower that that for the other groups in Ph. 1.

Response speed for G. 3 was slightly higher in Ph. 2 than in most of Ph. 1. Throughout all but the beginning of Ph. 2, response speed was approximately twice as high for G. 2a as for any other group, though this group's response speed continued to decline gradually from trial to trial in Ph. 2. For G. 2b response speed in Ph. 2 initially decreased to a level lower than that for G. 3 and then, during the remainder of Ph. 2, stayed at an essentially constant level lower than that for G. 3 on corresponding trials. Thus, comparing response speed between Gs. 2a and 2b in Ph. 2, performance was more suppressed for the group for whom the gradual increase in shock intensity had occurred outside the apparatus. An analogous finding in another experiment (Church, 1969) was discussed in S. IB-8.8.

For G. 1 response speed in Ph. 2 initially decreased more precipitously than for any other group at the beginning of either phase. Latent learning was thus evident for G. 1. In addition,
after the initial precipitous fall in response speed in Ph. 2, response speed for G. 1 stayed at an essentially constant level lower than that for any of the other groups in either Ph. 1 or 2. This effect was a contrast effect of the sort discussed earlier in S. IB-8.5. The relatively low response speed for G. 2b likewise represented a contrast effect.

The above findings for Gs. 1 and 3 were replicated in a later runway experiment with rats (Karsh, 1962). In this later experiment it was noted that rats ran progressively more slowly as they approached the goal box where they had been shocked. To place this observation in some perspective, recall from S. IB-3.5 that runway response speed for reward-trained rats progressively increases as the goal box is approached. In the present experiment punishment thus decreased response speed to a level inversely related to response speed before punishment.

IB-13.5. Shifts from Reward and the Depression Effect

In the two preceding sections latent learning was discussed in relation to nonreward-reward and nonpunishment-punishment shifts. Latent learning has also been shown for the third type of shift, a reward-nonreward shift, mentioned at the beginning of this chapter: Extinction was found to be faster for rats previously given 90 or 135 rewarded acquisition trials than for rats previously given 45 such trials (North & Stimmel, 1960).

Shifts from reward to nonreward represent a special case of shifts from higher to lower magnitudes of reward. The more gener-
al case has been investigated in a number of runway experiments in which the weight of food reward was shifted to a lower level from the first phase to the second. When the weight of food reward is thus shifted to a single lower level for all the rats in an experiment, response speed after the shift ordinarily becomes lower for rats that were given a higher weight of food reward (see Black, 1968). Such an effect is called the depression effect or the negative contrast effect and is analogous to the contrast effects occurring when punishment becomes contingent on a previously unpunished response in the manner described earlier in S. IB-8.5 and in the preceding section.

Depression effects could be evaluated in comparison to a control group for which reward magnitude in both Phs. 1 and 2 equals reward magnitude for the experimental groups after the shift, i.e., in Ph. 2. Obviously such an effect would be impossible if Ph. 1 were omitted. The depression effect may thus occur when and only when the number of Ph. 1 acquisition trials exceeds zero. By extension, this effect may be regarded as a direct function of the number of trials in Ph. 1. In fact, the depression effect has been found to be more pronounced with a greater number of trials in Ph. 1 (cf. Vogel, Mikulka, & Spear, 1966). Thus, in summary, the depression effect is a direct function of (a) the number of trials in Ph. 1, and, as indicated above, (b) the magnitude of the incentive shift between the phases. Recall from S. IB-13.3 that latent learning may similarly be regarded as a direct function of two such factors.
The occurrence of an "elation effect" or "positive contrast effect" with increased rather than decreased food reward is equivocal (Black, 1968; Spear, 1967) and may depend on the length of the runway used (Pubols, 1960). The depression effect was found not to occur unless rats were quite hungry (Ehrenfreund & Badia, 1962) and did not occur when a substantial decrease in hunger accompanied the downward shift in weight of food reward (Gragg & Black, 1967). Little or no negative contrast occurred in an experiment in which food presentation in the initial phase was not contingent on running down the runway (Spear & Spitzner, 1966).

In one experiment the depression effect was obtained with an abrupt but not a gradual decrease in the weight of food reward after Ph. 1 (Gonzalez, Gleitman, & Bitterman, 1962). In another experiment the depression effect was obtained with 1 but not with 68 days interpolated between Phs. 1 and 2, during which interval no runway trials took place (Gleitman & Steinman, 1964). In several runway experiments in which reward magnitude was varied as a function of sucrose concentration rather than weight of food, a depression effect was not obtained, even though response speed in acquisition training was parametrically greater with greater sucrose concentrations (e.g., Young & Shuford, 1955; see Black, 1968).

IB-13.6. Reward Shifts in Reversal Training

Reversal of choice learning has been thoroughly investigated in paradigms in which animals are individually trained to go left
with one cue and to go right with another to receive reward. In such paradigms the training procedure for choice reversal involves two shifts from initial acquisition training to reversal training: a reward-nonreward shift for the initially trained choice response and a nonreward-reward shift for the alternative choice response. Thus, in view of the findings that have been discussed regarding latent learning, the initial acquisition training procedure might be expected to facilitate choice reversal in comparison to a procedure with less initial training or with no initial training.

In fact, facilitation of reversal learning has frequently been shown for animals that are "overtrained" or, in other words, receive continued training after cue-directed choice learning as described above has taken place. Specifically, when the reward contingency is reversed between the cues, choice performance usually reverses to a greater degree or in fewer trials for overtrained animals than for nonovertrained animals (see Lovejoy, 1966; Mackintosh, 1965, 1969; Paul, 1965; Sperling, 1965a, 1965b; Wolford & Bower, 1969). This overtraining reversal effect occurs notwithstanding that choice performance for the overtrained animals may be superior before reversal. However, overtraining to a cue retards shifts from cue responding to consistent position (right or left) responding (see Mackintosh, 1965), and an overtraining reversal effect is usually absent after position training instead of cue training (e.g., Lovejoy, 1966; Paul, 1965; Sperling, 1965a, 1965b; Wolford & Bower, 1969). In fact, position overtraining may impair reversal learning. Such impairment coin-
cides with the fact that position-trained animals learn more quickly than do cue-trained animals (see Lovejoy, 1966; Wolford & Bower, 1969).

The overtraining reversal effect is greater for cues signaling parametrically greater reward (e.g., see Paul, 1965; Sperling, 1965a, 1965b). In other words, the overtraining reversal effect is greater with a parametrically greater magnitude of the reward shift for each choice response. Similarly direct relationships were discussed in the preceding section and in S. IB-13.3.
Part II

FIXATION OF BEHAVIOR

A. FIXATION IN RATS
Chapter 1

THE MAIER PARADIGM

IIA-1.1. Fixation

The usual procedures for demonstrating behavioral fixation consist of two consecutive phases in which rats must jump to the left or the right window in a jumping apparatus. The windows are individually locked to train the rats' choices between the windows, and the rats must therefore be constrained to jump (cf. S. IIA-2.2). A typical constraint is an electric shock that the rats can avoid and escape by jumping (see S. IIA-1.4).

Choices can be trained with an "insoluble problem" procedure in Ph. 1 (see S. IIA-1.5): One at a time, each window is locked on 50% of the trials in an irregular sequence, and cues as such are not present to indicate which window is locked. During this procedure rats typically learn to choose the window which, when previously chosen, was locked on proportionately fewer trials than was the other window. Similarly, most experimentally naive rats can readily be trained to choose the unlocked window when a window is consistently locked on one side or when visual cues signal which window is locked (see S. IIA-2.2). Thus, operationally, a locked window provides punishment for such rats.

In Ph. 1 of the usual fixation experiment, each rat is trained until its choices have become consistent (e. g., see S. IIA-1.5). Ph. 2 typically comprises a partial-reversal training procedure (see S. IIA-1.6). For example, if a rat has been
trained to jump consistently to the left window in Ph. 1, each window is locked, one at a time, on 50% of the trials in Ph. 2, and visual cues concomitantly signal which window is locked. Hence, the rat can consistently avoid hitting the locked window in Ph. 2 if the rat reverses its choices on half the trials and in response to the appropriate cue.

If rats are trained with an insoluble problem procedure or with some other suitable procedure in Ph. 1, most of the rats do not learn to avoid the locked window within an ample number of trials in Ph. 2 but continue to repeat consistently the choice that was trained in Ph. 1 (see S. IIA-1.7). Such rats are designated as fixated because their choices are no longer responsive to what constitutes punishment for experimentally naive rats. Fixation may thus be described as a learned inability to learn in terms of a given dimension of performance, e. g., in terms of choice performance in a jumping apparatus. Such an inability to learn may be operationally identified from the frequency distribution of performance levels that develops in Ph. 2 (or in some other applicable phase in special instances). This distribution is bimodal between animals that exhibit such an inability to learn and those remaining animals who do learn (see Ss. IIA-1.7 and IIB-3.1).

The prototypical method for demonstrating fixation was developed by Maier and associates (see Maier, 1949) and is called the Maier paradigm (e. g., Feldman & Green, 1967). The Maier paradigm or a related method has been followed in most fixation experiments
and will therefore be described in detail in this chapter. Maier (1949, Ch. 3) held fixation to be a laboratory analogue of compulsions, psychopathic behavior, irrational stubbornness, prejudice, and phobias in humans. Commenting on the applicability of Maier's fixation experiments, Mowrer (1950) stated his belief that

the absolutely central and most critical issue in clinical theory . . . is the question as to why so-called neurotic behavior is at one and the same time self-defeating and yet self-perpetuating, rather than self-eliminating [p. 434; italics in original].

Since fixation is learned through training with response-punishment contingencies, fixation might reasonably be regarded as the end product of incentive learning such as ordinarily occurs through response-punishment contingencies. However, the published data on fixation signify some paradoxical effects. For example, in two pertinent experiments, which will later be discussed in detail, 100% punishment at one window was used to train rats to choose the other window in Ph. 1. In one of these experiments, punishing this trained choice in Ph. 1 was found to perpetuate the same choice in the form of fixation in Ph. 2 (see S. IIA-3.7). In Ph. 1 of the other experiment, rats in one group were trained to jump to the window chosen of the first trial of this phase, and in Ph. 2 proportionately fewer rats were fixated in this group than in another group of rats that had been trained to jump to the initially unchosen window in Ph. 1 (see S. IIA-3.1). The rats thus tended more to become fixated against their initial preferences.

In view of such paradoxes, Maier (1949, 1956) advocated that
fixation develops through a process that differs from ordinary incentive learning. However, he failed to indicate any operational method for specifying the process itself as separate from the outcome of fixation (cf. Knöpelmacher, 1953a; Lawson, 1965). Other authors have since reinterpreted fixation, but like Maier they have not related fixation operationally to the familiar conceptions of incentive learning (e.g., cf. Feldman, 1957; Feldman & Green, 1967). The study of fixation has thus tended to remain a discipline unto itself, and perhaps for this reason the many fixation experiments by Maier and others have attracted only scant attention (see Yates, 1962, Ch. 1). Yet in view of the fact that choice and punishment are basic realities of behavioristic psychology, fixation would seem to represent a fundamental mode of behavior, a mode that is on a par with generalization and discrimination, for example.

If fixation and straightforward incentive learning were to be reconciled with each other, the many enigmatic aspects of fixation could be incorporated within the heuristic framework of well-established conceptions involving familiar learning processes. An especially satisfactory and efficient means for understanding fixation would thus be available. Much of the discussion herein will therefore center around a novel contention that fixation and straightforward incentive learning can be reconciled at the behavioral level. In particular, various literature findings on fixation will be interpreted in reference to the parsimonious concept that fixation is the end product of straightforward incentive
In Chs. 2 through 5 in Part IIA, the validity of this concept will be discussed and supported in detail. That discussion will form a groundwork for a subsequent chapter dealing with drug effects on fixation.

IIA-1.2. The Lashley Jumping Apparatus

Most experiments based on the Maier paradigm have used the Lashley jumping apparatus, an apparatus of the type that Lashley (1930) designed to investigate vision in rats. This apparatus as used in relatively recent experiments is designed as follows (e.g., Feldman, 1968; Houser & Feldman, 1971; see Feldman, 1948, for additional details). It has a jumping stand consisting of a 4½ in. x 8 in. grid that can supply .40 ma. of 120 v. current to a rat. From this stand a rat can jump to or through either of two 6 in. square openings in a nonadjoining wall. This wall is called a screen, and the openings are called windows. The distance between the screen and the jumping stand is adjustable.

From the jumping stand the windows lead to a 20 in. x 24 in. platform. Two colorless translucent plexiglas flaps serve as doors covering respective windows on the platform side. An unlocked door can easily be pushed open from the side of the jumping stand. Each door can be individually locked shut by means of a toggle switch. Suspended from springs 32 in. below the windows is a net to catch any rat that jumps to a locked door and falls.

The doors, though normally closed, can be kept open to varying degrees. Above the platform are 25 or 40 w. light bulbs that
can be turned on to illuminate either door individually. Originally projection lanterns were used to illuminate the doors.

Each trial in the Lashley jumping apparatus involves placing a rat on the jumping stand and allowing or constraining the rat to jump to a window. The details of this procedure will be discussed in the next two sections. With this procedure two types of performance can be measured. One is choice performance, which is the proportion of trials on which a rat jumps to a particular window. The second is latency, measured on each trial as the elapsed time between when the rat is placed on the grid and when a jump occurs.

The early fixation experiments used a Lashley jumping apparatus with a somewhat different design from that described above. The essential differences are as follows (e.g., cf. Maier, 1949, Ch. 2). First, the jumping stand did not consist of a grid and thus could not be electrified. Second, an opaque card rather than a translucent plexiglas door was placed in each window. On one of these cards was a solid white circle on a black background. On the other was a solid black circle on a white background.

If a window is locked, a rat may jump in such a way as to abort the potential impact of hitting the window. Such responses are therefore called abortive responses. Abortive responses that have been observed include jumping above the windows so that all four feet hit the screen, jumping to the right or left of the right or left window respectively, jumping so as to hit the locked window with the side of the body, and grasping the bottom ledge of the window (Maier, 1949, Ch. 2).
The apparatus is constructed in such a way as to minimize abortive jumping. For example, between the jumping stand and the screen is a ceiling immediately over the windows. Sometimes the jumping stand is enclosed on all sides except the side toward the windows so that rats cannot jump out of the apparatus.

IIA-1.3. Pretraining

Before the Maier paradigm procedure is begun, experimentally naive rats are "pretrained" to jump from the stand to the windows. One pretraining procedure is as follows (Liberson & Gagnon, personal communication, 1968). This procedure takes two weeks, five days per week. At no time during this procedure is either window locked or the light for either window turned on. On the first day, both windows are fully open, and the jumping stand is 1 1/2 in. from the screen. Four rats at a time are placed on the platform and allowed about 30 min. to move freely through the windows.

After the first day a rat on the jumping stand is allowed to jump freely to either window on certain trials. On other pretraining trials specified below, the rat is manually guided to a particular window in order to prevent consistent jumping to one window and thus to ensure that the rat will jump to both windows when the experiment proper begins. Accordingly, guidance during pretraining is always directed away from the window to which the rat jumped on the previous free trial. On both free and guided trials, if a rat does not go through a window spontaneously, the rat is turned toward the windows and pushed in order to force a
response. Each rat's daily pretraining is split into morning and afternoon sessions, since otherwise the rats tire too easily.

On the second day the windows are closed about $30^\circ$. The distance between the jumping stand and the screen is 3 in. in the morning and is sequentially $3\frac{1}{2}$ in., 4 in., and $4\frac{1}{2}$ in. on three afternoon trials. Two rats at a time are placed on the jumping stand and each is allowed three free jumps in the morning and three free jumps in the afternoon.

On the third day each window is closed a little more than on the second day, and the jumping stand is 4 or 5 in. from the screen. In the morning two rats at a time are placed on the jumping stand and allowed five free jumps each. In the afternoon and from this time on, one rat at a time is placed on the jumping stand. In the afternoon of the third day, three free jumps are allowed.

On the fourth day each window is open about 1 in. in the morning and $\frac{1}{2}$ in. in the afternoon. The distance between the jumping stand and the screen is 5 to 7 in. in the morning and is 6 to 8 in. in the afternoon. Each rat is allowed six free jumps in the morning and four free jumps in the afternoon. On the fifth day each window is open no more than $\frac{1}{2}$ in., and the jumping stand is 7 or 8 in. from the windows. Each rat receives five to seven trials with guidance in the morning and six or seven trials with guidance in the afternoon.

After the first week and until the end of the entire experiment, the windows are closed and a record is kept of the window to
which each rat jumps on each trial. Also after the first week, the jumping stand is 9 in. from the screen until the end of the experiment. Some investigators fix the distance at $8\frac{1}{2}$ in. instead (e. g., Houser & Feldman, 1971).

During the second week of the pretraining regimen discussed above, each rat is given 10 trials per daily session. Free choices are permitted on all trials besides Trials 3, 6, and 9 of each of these sessions. On these three trials the rats are guided except when the two previous jumps were to opposite windows. After the second week the rats are assigned to treatment groups in such a way that each group has an equal proportion of rats that chose a particular window on the majority of free trials during this week. The experiment proper is then begun.

With another pretraining procedure groups of rats are equated not only for position preferences but also for latencies (Feldman, 1968). The first part of this procedure resembles the procedure described above. Each rat is subsequently given four additional sessions, 10 trials per session, of a regimen that differs in only two ways from the experiment to follow. First, both windows are unlocked on every trial. Second, if a rat jumps to one window on three consecutive trials, it is manually guided to the other window on the next trial. These two restrictions are to ensure that each rat will jump to both windows and will thus be exposed to the incentive contingencies when the experiment proper begins. Latencies are measured during the four sessions and are thus measured under conditions approximating the experimental conditions to fol-
The groups of rats are then equated with regard to latencies.

IIA-1.4. The General Procedure

The procedure and typical results in the Maier paradigm are as follows (e.g., see Feldman & Green, 1967; Liberson, 1967; Maier, 1949; Yates, 1962). Each rat is given a series of daily experimental sessions. Usually each session consists of ten massed trials. On each trial in the earlier fixation experiments, one of the cards was placed in each window. With the current standard procedure, one window is illuminated ("bright") and the other window is dark on each trial. On certain trials in an irregular sequence, the cards or the dark and bright windows are interchanged from their positions on the previous trial, as shown in T.

IIA-1.4.

As this table indicates, that sequence has the following aspects. Each window is bright on half the trials of any session. Within any single session the bright-vs.-dark configuration of the windows is thus uncorrelated with the right-vs.-left dimension on which the bright-vs.-dark configuration is transposed. Among the first as well as the last five trials of any session, one window is bright on either two or three trials, as is the other window. On Trial 1 as on Trial 10, the bright side is alternated in regular sequence among sessions. A particular window may be bright for one, two, or at the most three consecutive trials within a session.
<table>
<thead>
<tr>
<th>Trial</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
<th>Session 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D B*</td>
<td>B* D</td>
<td>D* B</td>
<td>B D*</td>
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<tr>
<td>2</td>
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<tr>
<td>10</td>
<td>D* B</td>
<td>D B*</td>
<td>B D*</td>
<td>B* D</td>
</tr>
</tbody>
</table>

Sources. — Feldman and Green, 1967; Liberson and Gagnon, personal communication, 1968.

Note. — "D" designates "dark" and "B" designates "bright." Under each session the letters in the left and right columns describe the windows that an animal on the jumping stand faces on its left and right respectively. The same sequence as that in this table was followed in Maier paradigm experiments that used card patterns instead of illumination to configure the windows. After the first four sessions, the sequence shown repeats as often as is necessary for the duration of the experiment.

*Locked during Ph. 1, the insoluble problem phase.
The rats are deprived of food for 23 hours prior to each session, and during each session wet food is on the platform adjacent to the windows. On any given trial one window is locked and the other window is unlocked as described shortly. A rat that jumps through an unlocked window may eat. A rat that jumps to a locked window hits that window and falls into the net. A locked window is intended to provide the punishment essential to the experimental design.

In the early experiments rats that did not jump spontaneously were constrained to jump by means of an air blast or an electric wand. More recently the standard procedure has been to apply grid shock to a rat that has not jumped within 30 sec. after being placed on the jumping stand. This particular time interval allows sufficient latency variation so that latency can be measured as a function of food reward and of punishment at a locked window.

IIA-1.5. The Insoluble Problem Phase

The experimental sessions of the Maier paradigm are grouped into two consecutive phases. In Ph. 1 each window is locked on 50% of the trials in an irregular sequence. As T. IIA-1.4 indicates, this sequence can be characterized in the same manner as was the sequence for interchanging the dark and bright positions.

Thus, like the bright-vs.-dark configuration, the locked-vs.-unlocked configuration of the windows is uncorrelated with the right-vs.-left dimension within any single session. Hence, the dark window is locked on the left side as frequently as on the
right side within any given session, as is the bright window. Furthermore, the locked-vs.-unlocked configuration is uncorrelated with the bright-vs.-dark configuration within any two consecutive sessions, as T. IIA-1.4 indicates. Within any single session the dark window on a given side is locked on either two or three trials, as is the bright window.

Any likely sequence of choice responses will thus yield food on about half the trials of Ph. 1 but will result in punishment on the other half. Ph. 1 of the Maier paradigm is therefore called the insoluble problem phase (IPP). After about 40 or 50 trials in this phase, a rat's choice performance approaches 100% by one standard or another (e.g., Maier, Glaser, & Klee, 1940; Maier & Klee, 1943, 1945; Wilcoxon, 1952). For example, in the experiments with cards covering the windows, over 80% of the rats usually came to jump consistently to the window on a particular side, and the remaining rats developed a consistent pattern of jumping to a particular card. Likewise, after a sufficient number of trials with the window illumination procedure, most of the rats jump consistently to the window on a particular side, and the remaining rats jump consistently to the bright window or, rarely, to the dark window.

Any such performance pattern that emerges under the described conditions is called a stereotype. A stereotype may be designated more specifically as a symbol stereotype or a position stereotype depending respectively on whether stereotyped jumping is consistently directed to a particular card or to the window on a particu-
lar side. The eventually stereotyped response is not necessarily punished at a locked window on exactly half the trials on which this response occurs during the IPP, since the exact proportion depends not only on the sequence in T. IIA-1.4 but also on the sequence of choices for an individual rat. In one investigation proportionately fewer punishments were noted to occur for the eventually stereotyped response than for the alternative response ($p < .001$) (Feldman & Green, 1967). On the whole, then, stereotypes were apparently trained through punishment in terms of the percentage of trials on which a rat would hit a locked window (cf. S. IIA-3.6). However, additional unidentified factors also contributed in that 29% of the rats hit the locked window proportionately more often when performing the eventually stereotyped response than when the opposite choice response occurred. One such factor might be the force of impact against the locked window, for example, though this possibility has not been investigated.

In early fixation experiments, the IPP was continued for each rat until the rat had performed its stereotyped response on at least 95% of 160 consecutive trials. With more recent and current procedures, animals are given 160 IPP trials (16 sessions) altogether. In some Maier paradigm experiments, neither of these protocols was followed, but the difference was trivial. In one experiment, for example, the IPP consisted of 200 trials altogether (Wilcoxon, 1952).
IIA-1.6. The Soluble Problem Phase

In Ph. 2 as in Ph. 1, one window is locked on each trial. In Ph. 2, however, the side of the locked window is varied according to a trial sequence that is different from that in Ph. 1. In Ph. 2 this sequence permits the rats to avoid ever hitting a locked window if they differentiate between the card or illumination cues in terms of choice performance or if they perform only a single position (left or right) response. Ph. 2 of the Maier paradigm is therefore called the soluble problem phase (SPP).

In the SPP the specific trial sequence for locking the windows depends on what stereotype the individual rat has adopted. For rats with position stereotypes, the bright window or the window with a particular card is consistently locked, as Fig. IIA-1.6 illustrates. The window on a particular side was locked for rats with card symbol stereotypes. The window to which a position or card symbol stereotype is directed is thus locked on 50% of the trials in the SPP. The usual procedure in the SPP therefore requires rats to make partial-reversal shifts in choice performance or, in other words, to shift their jumping to the opposite window on 50% of the SPP trials, in order to avoid hitting a locked window.

Sometimes, however, rats are required to shift their jumping to the opposite window on 100% of the Ph. 2 trials and thus to make full-reversal shifts in choice performance. In particular, for rats with stereotypes directed to a bright window, the conventional procedure is to lock the bright window consistently. Simi-
Fig. IIA-1.6. A trial in Ph. 2, the SPP, of the Maier paradigm. The rat on the jumping stand is facing the bright "negative" (locked) window and the dark "positive" (unlocked) window. For a position stereotype directed toward the left window, the S+ for the locked-window contingency comprises the left-bright, right-dark configuration of the windows, and the S- comprises the left-dark, right-bright configuration. The S+ for this response is the S- for the alternative choice response of jumping to the right window, and vice versa. (Reproduced from an article by W. T. Liberson, A. Kafka, E. Schwartz, and V. Gagnon in International Journal of Neuropharmacology, 1963, Vol. 2. Copyrighted by Pergamon Press, 1963.)
larly, the dark window is consistently locked for those occasional rats with stereotypes directed to a dark window. Full-reversal shifts have also been required for purposes of making certain treatment comparisons (see S. IIA-6.2).

IIA-1.7. **Fixation in the Maier Paradigm**

The criterion for **breaking** is a single deviation from the stereotype during the SPP, and a common criterion for **solving** is that a rat after breaking jump to an unlocked window on 29 of 30 trials in three consecutive sessions. In the very first Maier paradigm experiment, a minority of the rats broke and solved within the first 200 of 300 trials of the SPP, and none of the remaining rats broke during these 300 trials (Maier, Glaser, & Klee, 1940). The levels of choice performance thus fell into a stable bimodal distribution within 200 trials of the SPP. Therefore, in subsequent experiments, rats not breaking within 200 SPP trials have been designated as fixated.

Since 200 trials of the SPP have thus been considered adequate to demonstrate fixation and solution, the SPP has consisted of 200 trials (20 sessions) in the standard Maier paradigm procedure. If rats with position stereotypes are given 200 SPP trials, only 8-50% or 5-20% of the rats break and solve with the card and window illumination procedures respectively. For the rats that break, solution typically requires an average of about 90 trials altogether in the SPP and almost never requires over 160 such trials, not counting the 30 criterion trials (e. g., Liberson et al.,
1963; Maier et al., 1940; Maier & Klee, 1943, 1945). Note that solving establishes a locked window as a punishment in Ph. 2 for those rats that solve.

In some experiments based on the Maier paradigm, breaking and solving have occurred after the 200th trial of an extended SPP, but only when a procedural change was introduced following this trial. In one experiment, for example, 19% of the fixated rats broke after time out between the 20th and 21st sessions of a 40-session SPP (Neet & Feldman, 1954). Likewise, in another experiment 20% of the fixated rats broke after a more prolonged (four months') time out, and an additional rat broke after various testing procedures, a further time out, and pentylenetetrazol injections (Maier & Klee, 1941). In several experiments, as discussed later in Ch. 7, Part IIA, drug administration was terminated or begun starting with the 21st session of an extended SPP, and a few of the fixated rats were observed to break after the 20th SPP session in all but one of these experiments. In this one experiment chlordiazepoxide administration was begun after completion of the IPP and was terminated starting with the 21st session of the SPP, and no rats broke after drug administration ended (Feldman & Lewis, 1962). None of these drug experiments was continued beyond 20 SPP sessions for rats receiving no drug in the SPP, except for a single undrugged rat, who failed to break in a 40-session SPP without a preceding IPP (Lewis & Feldman, 1964).
Chapter 2

THE NATURE OF FIXATION

IIA-2.1. Differentiation

As was mentioned in S. IIA-1.2, the construction of the Lashley jumping apparatus minimizes abortive jumping, but certain forms of abortive jumping still occur. For example, rats frequently hit a window ventrally rather than anteriorly (Liberson, 1967) and might even jump directly into the net. In an experiment in which abortive jumps were recorded along with choice performance, over half the fixated rats jumped abortively, and over half the nonfixated rats also jumped abortively before breaking and solving (Maier & Ellen, 1956). Most of these rats, both fixated and nonfixated, showed differential abortive jumping. That is, they jumped abortively to the unlocked window less frequently than to the locked window after about six SPP sessions on the average.

Differential abortive jumping was also reported in other experiments (Maier & Ellen, 1955; Maier, Glaser, & Klee, 1940) and may be viewed as differentiation of choice performance. The choice in this case is not between the usual leftward and rightward responses but is between abortive and nonabortive jumps, if responses are defined and dichotomized as such. It should be noted, however, that the term "choice performance" hereafter will refer to the choice between jumping to the left and right windows except as stated otherwise.

Latency differentiation occurs similarly to differential
abortive jumping: As the SPP progresses, rats' latencies tend to decrease for stereotyped jumps to the unlocked window and to increase for stereotyped jumps to the locked window (e.g., Feldman, 1953, 1964; Liberson, Feldman, & Ellen, 1959a; Liberson, 1967; Liberson & Karczmar, 1969; Maier et al., 1940; Neet & Feldman, 1954; Wilcoxon, 1952). Such latency differentiation occurs for fixated rats as well as for nonfixated rats before breaking. Fig. IIA-2.1 illustrates latency differentiation and also illustrates, incidentally, an observation that average latency remained well below 30 sec. even for jumps to the locked window. The rats thus tended to avoid rather than to escape the shock administered at 30 sec. Latency differentiation signifies that the contingency between jumping and hitting a locked window decreases performance—namely, jumping speed—in comparison to the absence of such a contingency. Thus, in terms of jumping speed, a locked window, compared to an unlocked window, serves to punish stereotyped jumping in Ph. 2.

Differentiation of latencies and of abortive jumping indicates sensitivity to the ongoing locked-window contingency on the fixated choice in Ph. 2. The Maier paradigm in disclosing such sensitivity is an especially revealing method for demonstrating fixation. Latency differentiation may precede a shift of choice performance not only in fixation experiments but in other types of experiments in which a partial-reversal shift in locomotor choice performance is required as in the usual SPP (e.g., cf. Mackintosh, 1965; Mähut, 1954). In the Maier paradigm the interesting aspect of latency differentiation is that it can occur without a
Fig. II A-2.1. Latencies during the Maier paradigm procedure. The curves represent averages from experiments with 80 rats (Liberson, 1964). As the SPP progressed, latencies increased for jumps to the bright "negative" (locked) window and decreased for jumps to the dark "positive" (unlocked) window. The rats had to jump within 30 sec. to avoid podal shock. (Reproduced from an article by W. T. Liberson, R. S. Feldman, and P. Ellen in Neuropsychopharmacology. Copyrighted by Elsevier Publishing Co., 1959.)
subsequent change in choice performance.

As was noted in S. IIA-1.6, rats are sometimes required to make full-reversal shifts in choice performance in the SPP, though the more usual requirement is a partial-reversal shift. With a full-reversal requirement as with a partial-reversal requirement, the usual bimodal distribution of performance levels is obtained (cf. S. IIA-6.2). In fixation experiments the only reason that a partial-reversal rather than a full-reversal shift is usually required is presumably because the partial-reversal requirement permits differentiation to be observed for fixated rats.

IIA-2.2. Problematic Interpretations and Negative Findings

Why do the majority of rats in the Maier paradigm continue their stereotypes in the face of punishment (and lack of food reward) that effects solving for nonfixated rats and effects differentiation for fixated and nonfixated rats? The answer is not that the contingencies of food vs. a locked window lack any capacity to support choice learning for the majority of rats, since these contingencies largely support learning of a stereotype in the first place, as was indicated in S. IIA-1.5. Moreover, if the IPP is omitted, the majority of rats can be trained to jump to a particular card (e.g., Maier & Ellen, 1951, 1952; Maier & Klee, 1943) or illumination (e.g., Lewis & Feldman, 1964), and all the rats can generally be trained to jump to the window on a particular side (e.g., Maier & Klee, 1943; Wilcoxon, 1952), with the procedures of the SPP. Fixation thus represents learning carried over from
the IPP to the SPP.

Fixation may appear to be "maladaptive" or "neurotic." However, as the discussion proceeds, it should become evident that fixated behavior in the Maier paradigm is more "rational" than it might appear to be on the surface. In any case, such characterizations are only value judgments. The findings of the following experiment illustrate the conundrums inherent in trying to classify a fixated response as "rational" or "neurotic."

After cats had been trained to procure food, they were punished for doing so (Watson, 1954). Some of them continued to procure food, whereas others would not do so and starved as a result. The performances of the cats thus fell into a bimodal distribution. Since procuring food signified failure to learn through the punishment contingency, this behavior might be regarded as fixation. Yet such fixation does not seem more "neurotic" or "maladaptive" than the behavior of the cats that starved.

One prominent fixation theory, Maier's (1949, 1956) frustration theory, is essentially circular (Knöpfelmacher, 1953a; Lawson, 1965) and thus provides no information beyond what is evident from the findings to be discussed herein. Another fixation theory takes the avoidance = fear model as a premise (e.g., Farber, 1954). This fixation theory need not be considered here, since it was concluded in Ch. 11, Part IB, that the avoidance = fear model is implausible after detailed consideration of the pros and cons of the model.

In one experiment conforming to the Maier paradigm, a para-
metrically increased amperage of the shock produced a decrease in latency but had absolutely no effect on the proportion of fixated rats (Feldman & Green, 1967). Another experiment followed the usual procedure of the Maier paradigm except that no shock or air blast was given (Klee, 1944). Latencies were in the order of hours, and yet fixations occurred. In this experiment, as in most fixation experiments with the Lashley jumping apparatus, rats were food deprived and received food upon jumping through an unlocked window. However, fixation and latency differentiation occur when rats receive no food reward in procedures otherwise conforming essentially to the Maier paradigm (Liberson & Karczmar, 1969; Liberson, Karczmar, & McMahon, reported in Liberson, 1967).

As T. IIA-1.4 of the previous chapter indicates, the reward and punishment sequence for a stereotyped response is biased in respect that neither reward nor punishment on one trial precedes reward or punishment on the next trial for exactly 25% of the IPP trials. However, the resultant candidates for trace cues fail to support latency differentiation in the IPP (Feldman & Waite, 1957). The role of sequential bias was examined in an experiment in which both windows were simultaneously locked or unlocked on alternate trials in Ph. 1 of a procedure that otherwise conformed to the Maier paradigm (Cadell, 1960). Latencies of stereotyped responses were observed to be higher on the trials on which both windows were locked than on the intervening trials in Ph. 1. The sequential bias thus supported differentiation between trace cues. In the SPP the proportion of fixated rats was insignificantly low-
er for rats subjected to the procedure just described than for control rats subjected to the usual procedure of the Maier paradigm. Fixation in the Maier paradigm thus bears no clear relationship to the punishment sequence per se.

As indicated above, fixation represents learning carried over from the IPP to the SPP. Therefore, since a change in a cue may produce a generalization decrement in learning (cf. S. IB-3.2), a generalization decrement in fixation might be expected if the cues in the IPP were to differ physically from the cues in the SPP. That is, the incidence of fixation might be lower with such a change than with an unaltered Maier paradigm procedure, in which the cues in the IPP do not differ from the cues in the SPP. The following experiments bear on the issue.

IIA-2.3. Generalization Decrements in Fixation

In one experiment the IPP procedure was modified in respect that both windows were consistently bright or dark for Gs. 10 and 20 respectively (Feldman & Green, 1967). As might be expected, all the rats developed position stereotypes. Ph. 2 resembled the usual SPP, with only one window at a time being illuminated, but the unlocked window was the bright window for G. 01 and was the dark window for G. 02. Thus, the illumination stimulus in Ph. 1 was either a left-bright, right-bright configuration or a left-dark, right-dark configuration, whereas the illumination cues in Ph. 2 were the left-bright, right-dark configuration and the left-dark, right-bright configuration. In short, the illumination
stimuli were changed between Phs. 1 and 2. A generalization decrement might thus have been expected to occur from Ph. 1 to Ph. 2 (cf. S. IB-3.2). That is, insofar as fixation reflects learning carried over from Ph. 1, proportionately fewer rats might have been expected to develop fixations with the present procedure than with the usual Maier paradigm procedure.

In Ph. 2 every rat in G. 01 solved, and 29% of the rats solved in G. 02. Thus, in accordance with expectation, proportionately more rats solved in G. 02 than solve in the usual Maier paradigm (cf. S. IIA-1.7), though the difference is relatively small and is thus only suggestive. The Ph. 2 procedure for G. 01, on the other hand, was not comparable to the procedure of the Maier paradigm, since the rats in G. 01 were required to jump to the bright window in Ph. 2, whereas rats are generally required to jump to the dark window in Ph. 2 of the Maier paradigm (cf. S. IIA-1.6).

As indicated above, proportionately more rats solved in G. 01 (bright correct) than in G. 02 (dark correct). This difference is not particularly enigmatic, since preference for the bright window is usually more frequent than is preference for the dark window, in the absence of opposing effects. For example, as was implied in S. IIA-1.5, rats form bright stereotypes more readily than dark stereotypes. Perhaps preference for the bright window is due to a stimulus-specific effect of the illumination cues (cf. S. IB-3.3) or to a reward effect of illumination after jumping (cf. Ss. IB-1.2, IB-2.2, and IB-2.5).
The results of the following experiment corroborate the foregoing results. In Ph. 1 the left window was consistently bright, and the right window was consistently dark, in what was otherwise a standard IPP (Feldman & Green, 1967). In this phase 63% of the rats formed bright-left stereotypes, and the remaining 37% formed dark-right stereotypes.

Ph. 2 was a standard SPP, with the dark window consistently unlocked, and with the illuminated side varied from trial to trial in the usual sequence. Thus, for the rats that formed bright-left stereotypes, solution required a change in performance to a bright-left, dark-right configuration cue. Therefore, since this cue was presented in both phases, no generalization decrement was to be expected for these rats. That is, the incidence of fixation would not be expected to have been lower for these rats than for rats in the usual Maier paradigm. In accordance with this expectation, only one (8%) of these rats solved in the experiment.

However, the incidence of solutions was 29% for the rats that had formed dark-right stereotypes, suggesting a generalization decrement for these rats. A generalization decrement might have been expected for these rats, since solution for them involved a change in performance to a dark-left, bright-right configuration cue that had not been presented in Ph. 1. In fact, the incidence of solutions was the same for these rats as for the rats with a comparable response requirement in Ph. 2 of the preceding experiment.

In summary, the incidence of solutions was greater—in both
experiments—for rats that might have been expected to show a generalization decrement than for rats in the usual Maier paradigm. However, this effect was slight, and these experiments did not themselves incorporate control groups subjected to the procedure of the standard Maier paradigm. In the latter experiment, moreover, the two groups of rats were demarcated not by random selection but by their preferences in Ph. 1. Thus, the results of these experiments only suggest generalization decrements.

IIA-2.4. The Specificity of Fixation

Insofar as fixation represents learning as maintained in the two preceding sections, the question arises whether such learning is ordinary incentive learning. This issue will be addressed shortly. For present discussion purposes, if fixation is assumed to represent incentive learning, fixation should be response-specific in the Darwinian sense, since incentive learning in general tends thus to be response-specific (e.g., see S. IB-2.1).

In fact, certain experiments have shown that fixation of jumping responses does not carry over to other responses besides jumping. However, since those other responses were evaluated under stimulus conditions differing from those under which fixated jumping occurred, it is uncertain whether these experiments indicated response specificity or generalization decrements or both. These experiments are nevertheless of interest because both response specificity and generalization decrements are of interest with respect to fixation.
In one of these experiments rats were subjected to the usual procedure of the Maier paradigm and in addition could walk along runways to either window on alternate trials (Feldman, 1953; cf. Ellen & Feldman, 1958). During the SPP some of these rats learned to walk to the unlocked window, and yet their jumping stereotypes persisted for the 200 trials without the runways. Other rats had positional jumping fixations with nonpositional walking fixations, or nonpositional jumping fixations with positional walking fixations, or positional jumping and walking fixations to opposite sides. In another experiment rats with right or left jumping fixations showed no corresponding tendency to turn right or left in a maze and could be trained to turn either way with no more training trials than were required by nonfixated rats (Maier, 1949).

IIA-2.5. Punishment Effects on Fixation

It will be maintained herein that fixation is the end product of straightforward incentive learning, avoidance learning specifically. More precisely, it will be maintained that breaking and solution occur if and only if ongoing punishment of the stereotyped response is effective enough in Ph. 2 to overbalance earlier punishment of the alternative choice response, which will be called the nonstereotyped response for present discussion purposes. Fixation as manifested in Ph. 2 should thus become increasingly probable with increasingly effective punishment at the window that is "incorrect" in Ph. 1, the window to which nonstereotyped jumps are directed.
Of course, in order for this statement not to be logically circular, the effectiveness of such punishment must be operationally evaluated independently of the incidence of fixation. Also, the effectiveness of punishment as such has meaning only in terms of punishment learning. With these points in mind, punishment of the nonstereotyped response may be evaluated as to its effectiveness in Ph. 1 as follows.

1. If the punishment contingency on the nonstereotyped response is parametrically varied in Ph. 1 with other procedural factors constant, punishment of this response is by definition more effective with the procedure that supports faster learning of the stereotyped response and thus supports greater overall avoidance of the nonpreferred window in Ph. 1.

2. Insofar as that contingency does not vary in Ph. 1, punishment at this window may be regarded as being effective in direct relation to the parametric number of punished jumps to this window. The rationale for this criterion is that individual incentives generally have a cumulative behavioral effect or a cumulative probability of producing a behavioral effect. Consider, for example, the commonplace learning curve of performance by trials (e.g., cf. S. IB-1.2). Also, in the Maier paradigm consistent avoidance of a window requires an accumulation of trials (see S. IIA-1.5) and thus of punishments at that window in Ph. 1.

3. If the punishment contingency on the nonstereotyped response is parametrically varied, correspondingly longer latencies (lower jumping speeds) for this response indicate more effective
punishment by the definition of punishment.

Whereas the foregoing indices apply to punishment of nonsteretyped responses in Ph. 1, indices to be discussed in S. IIA-4.5 and elsewhere apply to the aforesaid counterbalancing factor, namely, punishment of stereotyped responses in Ph. 2. As various findings are discussed herein, it will be noted that they support the above proposal that the incidence of fixation increases with increasingly effective punishment at the window eventually nonpreferred in Ph. 1. These findings thus suggest that fixation represents trained avoidance of that window. Since fixated rats do not jump to that window in Ph. 2, this avoidance cannot undergo extinction. Hence, behavior is caught in a vicious circle and is thus "self-defeating and yet self-perpetuating," as Mowrer (1950, p. 434, italics in original) described fixation.

Fixation thus precludes occurrence of the response whose occurrence is necessary in order for avoidance, manifested as fixation, to undergo extinction. In other words, fixation precludes the response variation that is necessary for breaking. Recall from S. IA-4.6 and elsewhere that such response variation is the initial stage of the Darwinian process of incentive learning. Fixation, as a failure to learn, can thus be considered a correlate of the Darwinian nature of incentive learning.

IIA-2.6. Reward Effects on Fixation

In one experiment jumps through an unlocked window yielded no food until late in the SPP (Liberson & Karczmar, 1969). Then,
when food became available, the fixated rats' latencies decreased rapidly for jumps to the unlocked window. The food thus served apparently as a reward. Therefore, in view of the fact that rats usually receive food for jumping through an unlocked window in the Maier paradigm, the foregoing discussion of punishment might be expected to apply conversely to food as a reward. Empirically, however, reward effects on fixation are problematic for reasons that will shortly become apparent.

In Ph. 1 of an experiment to be described in S. IIA-3.6, punishment and food reward were parametrically varied in terms of the proportion of trials on which the nonstereotyped response would yield punishment and would therefore yield no reward. Thus, in terms of choice performance in Ph. 1 (cf. Criterion 1 of the preceding section), a parametric increment in punishment effectiveness was indistinguishable from a parametric decrement in the effectiveness of the reward. Therefore, although the results suggest a direct relationship between the incidence of fixation and the effectiveness of the antecedent punishment of the nonstereotyped response, the same results alternatively or additionally suggest an inverse relationship between the incidence of fixation and the effectiveness of reward for this response. These results thus accord not only with the foregoing proposals concerning punishment but also with converse proposals about food reward.

However, in an experiment to be described in S. IIA-3.1, the nonstereotyped response consistently yielded punishment for certain rats and thus never yielded reward, and still the effective-
ness of this punishment—in this case the number of punishments—was directly related to the incidence of fixation, as the proposals in the preceding section would indicate. Moreover, findings to be discussed in S. IIA-3.4 indicate that the incidence of fixation is directly related to the number of both punished and food-rewarded nonstereotyped responses in Ph. 1 when both of these factors vary together in the same direction. Such effects agree with the proposals of the preceding section but disagree with any converse proposals about reward. Thus, in terms of the proposals made in the preceding section, the punishment factor seems to overshadow a possibly opposing reward factor in such cases.

In summary, the proposals of the preceding section seem applicable regardless of whether the effectiveness of punishment is varied in direct, null, or inverse relation to the effectiveness of food reward. Thus, in procedures resembling that of the Maier paradigm, food reward might distinctly influence the incidence of fixation only if the effectiveness of such reward were parametrically varied without concomitant variation in the effectiveness of punishment. Such reward effects on fixation have yet to be established. The emphasis in the preceding section was therefore on punishment, and the emphasis in the succeeding chapters will likewise be on punishment. In the Maier paradigm the relative weakness of a possible reward effect is associated with the fact that rats often do not eat the food that is available on jumping through an unlocked window (Feldman & Green, 1967).
Chapter 3

FIXATION AS TRAINED BEHAVIOR

IIA-3.1. Fixation After Position Training

In certain experiments rats have been subjected to a procedure conforming to the Maier paradigm except that a single window or card was locked on all the trials in Ph. 1, and the other window or card was correspondingly unlocked (e.g., see S. IIA-3.7 and Ch. 6, Part IIA). This procedure has been called position training or symbol training depending respectively on whether the window on a particular side was consistently locked or whether the window with a particular card was consistently locked. With this procedure rats typically require about two or three trials in Ph. 1 before jumping consistently to the unlocked window. This is less than one tenth the average number of trials required for rats to develop stereotypes in an IPP (cf. S. IIA-1.5).

Position- or symbol-trained rats may become fixated. Fixation in such rats might be expected in view of the foregoing discussion in S. IIA-2.5 equating fixation and trained avoidance, since position training and symbol training amount to avoidance training in Ph. 1. In line with that discussion, the results of the following experiment accord with the proposal that fixation is the end product of avoidance learning and thus that fixation is a correlate of the Darwinian nature of incentive learning.

In Ph. 1 the rats in G. 1 were position trained to jump to the window chosen on the first trial of this phase, whereas the
rats in G. 2 were trained to jump to the initially unchosen window in Ph. 1 (Maier, Glaser, & Klee, 1940). As might be expected, the rats in G. 2 incurred more punishments at the incorrect (locked) window than did the rats in G. 1. Thus, by the number-of-punishments criterion stated earlier in S. IIA-2.5, this punishment was more effective for the rats in G. 2. Hence, the proposal (S. IIA-2.5) that fixation represents trained avoidance indicates that these rats should have shown the higher incidence of fixation in Ph. 2, as the case was: Proportionately more rats became fixated against their initial preferences than toward their initial preferences. The paradoxicalness of this finding is thus resolved (cf. S. IIA-1.1).

IIA-3.2. Guidance in Ph. 2

In the preceding experiment, as in various other experiments to be discussed, the number of nonstereotyped jumps was confounded with the number of punishments of the nonstereotyped response. Therefore, although the proportion of fixated rats did increase with the number of such punishments in Ph. 1, this result does not conclusively indicate that the proportion of fixated rats increased as a result of punishment as opposed to mere occurrence of the nonstereotyped response. This issue is resolvable on the basis that the behavioral effect of an incentive diminishes with extinction training. With ordinary extinction training, as in numerous experiments discussed in Part I, an incentive formerly presented contingently on a response is no longer presented when that
response occurs. Thus, insofar as fixation is an effect of punishment of the nonstereotyped response, fixation should be lost during extinction training whereby that response occurs without yielding punishment any longer. Such extinction training can be enforced by manually guiding a fixated rat to the nonpreferred window—i.e., by constraining the rat to make nonstereotyped responses—when that window is unlocked in Ph. 2. Such manual guidance might thus be expected to erase fixations resulting from prior punishment, as opposed to mere occurrence, of nonstereotyped responses.

Manual guidance to the unlocked window has been investigated in experiments in which fixated rats received such guidance on each trial in a block of additional SPP trials immediately following the usual 200 trials (Liberson et al., 1963; Maier & Klee, 1943) of following more than the usual 200 trials (Maier, Glaser, & Klee, 1940). After the guidance was discontinued, all the rats solved immediately in a continuation of the soluble problem regimen. Guidance thus erased their fixations in accordance with the premise that fixation accompanies prior punishment of nonstereotyped responses. This effect of guidance thus accords with the previous suggestion in S. IIA-2.5 that the likelihood of fixation varies directly with the effectiveness of prior punishment of nonstereotyped responses and, more generally, that fixation depends on whether such punishment is effective enough to overbalance ongoing punishment of stereotyped responses.

This idea implies that if previous punishment of nonstereoco-
typed responses loses its potential behavioral effect through ex-
tinction, this loss might have little influence on choice perform-
ance besides permitting punishment of stereotyped responses to al-
ter choice performance. Thus, if the effect of guidance is indeed
to permit extinction, guidance might not affect choice performance
as strongly as in the experiments cited above if stereotyped re-
sponses are unpunished in Ph. 2. Such appears to be the case from
the findings of the following experiment.

The procedure in Ph. 1 consisted of insoluble problem train-
ing for half the rats in Gs. 1 and 2 each (Maier & Klee, 1945).
The other half received position training instead. For G. 1 Ph. 2
was a standard SPP. The procedure in Ph. 2 differed for G. 2 in
respect that both windows were unlocked during the first 100 tri-
als of this phase. Also, during the first 30 trials of Ph. 2, the
rats in this group received manual guidance to the card that was
to be the unlocked card after the first 100 trials of Ph. 2.

Few rats in G. 2 "solved" during the 70 no-punishment trials
following guidance. However, with the subsequent introduction of
punishment, more rats solved, and in the end more rats solved in
G. 2 than in G. 1. Thus, guidance served to prevent fixation but
was fully effective only in conjunction with punishment of stereo-
typed jumping. The effect of guidance thus appears largely to
represent extinction rather than learning-by-doing. In the usual
SPP with punishment throughout, solution on free-choice trials has
been observed for all rats receiving manual guidance to the un-
locked window on every other trial throughout this phase (Maier &
The results of one experiment qualify the conclusion that manual guidance facilitates solution by allowing extinction. It was found that if animals are "soothed" by handling before each trial, this handling in itself eliminates fixations (Haslerud, Bradbard, & Johnstone, 1954). However, guidance with a transparent screen was as effective as manual guidance. Manual guidance thus may facilitate solution by "soothing" rats but is probably effective at least in part because it exposes rats to the altered contingency at the nonpreferred window and thus permits extinction.

IIA-3.3. Biased Symbol Training

In Ph. 1 of one experiment, a white card was consistently unlocked, a black card was consistently locked, and grid shock was used to force jumps (Bitterman & Coate, 1950). The two cards covered the two windows on each trial of Ph. 1, but for each rat the white card was on one side, the "biased" side, on 8 of the 10 trials in each session in Ph. 1. This side was the initially preferred side for half the rats and was the initially nonpreferred side for the remaining rats in each experimental group, G. 1 and G. 2.

In Ph. 2 each card appeared on a particular side on exactly half of each rat's trials. Throughout Ph. 2 the window on one side was consistently locked, and the window on the other side was consistently unlocked, for each rat. Thus, in order to solve, a
rat had to jump consistently to one side in Ph. 2. The unlocked window was on the biased side for G. 1 and was on the nonbiased side for G. 2.

Breaking and solution thus involved a change in performance to different cues for the different groups. For G. 1 this cue comprised a black card on the biased side and a white card on the nonbiased side. For G. 2 this cue comprised a white card on the biased side and a black card on the nonbiased side. The proportion of fixated rats was found to be lower for G. 1 than for G. 2.

Unfortunately, it was not reported how many jumps were directed to the black card on each side in Ph. 1. However, since this card appeared more frequently on the nonbiased side, it is reasonable to speculate, for purposes of discussion, that the rats made more jumps to this card on the nonbiased side than on the biased side in Ph. 1. In this case the number of punishments would have differed correspondingly between the biased and nonbiased windows in Ph. 1.

Assuming this to be the case, breaking and solution for G. 1 involved a change in performance to a cue (the black-biased, white-nonbiased configuration, as indicated above) that had been associated with relatively few punishments for the nonstereotyped response, jumping to the black card. For G. 2, on the other hand, breaking and solution involved a change in performance to a cue (the white-biased, black-nonbiased configuration) that had been associated with relatively many punishments for the nonstereotyped response. The incidence of fixation would thus be expected to
have been lower for G. 1 than for G. 2 if the incidence of fixation increases with increased punishment of the nonstereotyped response in Ph. 1, as was maintained in S. IIA-2.5.

IIA-3.4. Permitting and Punishing Nonstereotyped Responses

The following experiments provide support for the present view that fixation represents trained avoidance. In one experiment the IPP was modified in respect that one window was always covered with black paper (experiment reported in Feldman & Green, 1967, and done with Ellen & Liberson). During this phase the rats jumped only to the other window. In the SPP the black paper was removed, and the dark or bright window was correct (unlocked) for separate groups of rats. All the bright-correct rats solved, and 40% of the dark-correct rats solved, a substantially higher percentage than obtains in the unaltered Maier paradigm (cf. S. IIA-1.7).

In a different experiment a sheet of plexiglas was used to guide each rat to the initially preferred side on every trial of what was otherwise a standard IPP (Feldman & Green, 1967). The initially preferred side was determined from performance during pretraining. All the rats solved, again in contrast to the findings with the usual Maier paradigm.

Comparing the above findings with those of the unaltered Maier paradigm, jumping in Ph. 2 appears less likely to shift to a window where previous jumps were punished than to a window at which jumping was not directed and was therefore not punished in
Ph. 1. The above findings thus conform with the suggestion made earlier in S. IIA-2.5, that the incidence of fixation ought to increase when the nonstereotyped response has been punished more effectively, as on relatively more occasions, in Ph. 1. As the present interpretation emphasizes one factor—the number of punishments for one response—that varied between the usual IPP procedure and the procedures in Ph. 1 of the foregoing experiments, so might other interpretations emphasize other factors varying between these procedures. The present interpretation of the above findings is thus open to qualification and indeed will be qualified in the next section. However, an analogous finding obtained in the following experiment is not similarly open to qualification since this finding comprised a within-group comparison and was thus unrelated to procedural variations in Ph. 1.

The usual Maier paradigm procedure was followed except that a third window was introduced in the SPP (Ellen, 1956). For certain rats this window was to the left or right of the window to which stereotyped jumping was directed, depending respectively on whether stereotyped jumping was directed to the left or right window. These rats jumped to the new window even though they were fixated against jumping to the old nonpreferred window.

In paraphrase, jumping was more likely to shift to the window toward which jumping previously had not been directed and therefore had not been punished. This finding like the foregoing findings thus conforms with the view that the incidence of fixation is positively related to the effectiveness of prior punishment of the
nonstereotyped response. Moreover, the rats jumped to the new window selectively on the trials on which the otherwise preferred window was locked. Thus, congruently with the present interpretation, fixation against the (old) nonpreferred window was not related to ineffectiveness of punishment of the stereotyped response (cf. S. IIA-4.5).

IIA-3.5. Guidance in Ph. 1

The findings of the following experiment qualify the interpretation given for some of the findings of the preceding section. The procedure for G. 1 conformed to the usual Maier paradigm (Feldman & Green, 1967). The procedure for Gs. 2 and 3 differed in respect that a plexiglas screen was sometimes used to guide the rats in these groups to a particular window in Ph. 1. In Ph. 1 the rats in G. 2 were allowed five free jumps on the first five trials of each session and then received five trials with guidance so that among the left vs. right x bright-directed vs. dark-directed x punished vs. unpunished responses, each occurred on one eighth of the trials in Ph. 1 (cf. S. IB-10.7). The rats in G. 3 were guided on every trial in Ph. 1 and in such a way that they made the same responses as did yoked partners in G. 2. Latency during the IPP did not differ significantly between free-choice trials and guidance trials either within G. 2 or between Gs. 1 and 3. However, the proportion of fixated rats did differ among Gs. 1, 2, and 3, being 88%, 43%, and 0% respectively.

These findings may be interpreted as follows. The environ-
ment in the jumping apparatus was somewhat novel for G. 3 in Ph. 2 in respect that the guidance screen was consistently present in Ph. 1 but was absent in Ph. 2. For G. 2, on the other hand, the environment of the apparatus was not similarly novel in Ph. 2 in that the rats in this group had received trials without this screen in Ph. 1. Thus, considering fixation to be a manifestation of learning carried over from Ph. 1 (cf. Ss. IIA-1.1 and IIA-2.2), the element of novelty would be expected to have possibly resulted in a tonic generalization decrement and thus in a decreased tendency for G. 3 to show fixation (cf. S. IIA-2.3).

In any case, the guidance procedure per se decreased the likelihood of fixation, and this finding qualifies the interpretation given in the preceding section for the experiment in which rats were guided to a single window on every trial of Ph. 1. The interpretation given then was that this procedure reduced the incidence of fixation because the rats were not punished for performing a nonstereotyped response in Ph. 1. This interpretation cannot, however, be considered invalid in that the possible occurrence of a generalization decrement cannot be invoked to explain the findings of the three-window experiment discussed in the preceding section. In this experiment a generalization decrement might have occurred but cannot account for the fact that the rats shifted their jumping to the new window but not to the old nonpreferred window.

The results of the foregoing guidance experiment were not reported in sufficient detail to allow an unequivocal analysis of
the aforesaid difference in fixation between Gs. 1 and 2. Possibly this difference was related to relative novelty of the apparatus in Ph. 2, just as the difference between Gs. 2 and 3 may have been due to the novelty factor in the absolute sense of novel vs. not novel. Alternatively, if guidance with the screen prevented formation or continuation of stable performance patterns as does manual guidance in Ph. 2 (cf. S. IIA-3.2), then the non-stereotyped response of Ph. 2 may have occurred on free-choice trials throughout most of Ph. 1 for G. 2. This response would then have occurred more times for G. 2 than for G. 1 in Ph. 1.

This response might thus have yielded closer to 50% punishment for G. 2 than for G. 1, since deviations from an eventual probability tend to be smaller with larger samples, as with a larger number of nonstereotyped jumps in this case. For G. 1 this deviation should have tended to be above 50%, since nonstereotyped responses usually receive proportionately more punishment than do stereotyped responses, as was discussed in S. IIA-1.5. G. 1 might thus have received proportionately more punishment at the nonpreferred window than did G. 2.

A finding discussed in the next section indicates that proportionately more punishment at the nonpreferred window may be regarded as more effective punishment at this window. Punishment of the nonstereotyped response might thus have been more effective for G. 1 than for G. 2 on free-choice trials. The proportion of fixated rats would then be expected to have been higher for G. 1 than for G. 2 if the incidence of fixation increases with increas-
ingly effective punishment of the nonstereotyped response in Ph. 1, as has been maintained in this chapter. Such a difference would agree with the actual results indicated above.

The foregoing analysis assumes that the rats in G. 2 made more nonstereotyped responses and thus implies that these rats incurred more punishments for this response in Ph. 1 than did the rats in G. 1. In previous sections it was asserted that the number of such punishments is directly related to the incidence of fixation. Thus, with other factors equal, the incidence of fixation should have been greater for G. 2 than for G. 1, but it has been noted that the opposite effect was obtained, and the foregoing analysis indicates a factor—namely, the proportion of punishments—that may have differed between the groups. Apparently, then, the number-of-punishments factor had little or no consequence in the present experiment. Why? The number of nonstereotyped responses is much greater with an IPP—and should thus have been much greater for all the groups in the present experiment—than for the low-fixation groups in the experiments in which the low incidence of fixation was related to a paucity of punished nonstereotyped responses. In the present experiment the number of punishments may thus have been inconsequential because of an asymptotic ceiling effect.

IIA-3.6. The Proportion of Punishment Trials in Ph. 1

Admittedly the above interpretation is too speculative to do much more than to put the findings into perspective and to suggest
variables that should be examined. An assumption made in the foregoing discussion was that the proportion of fixated rats might be expected to vary directly with the proportion of punished non-stereotyped responses. The results of the following experiment support this assumption.

The procedure of the Maier paradigm was followed for G. 1 of rats (Wilcoxon, 1952). The procedure differed for G. 2 only in respect that one of the windows was locked on 100% of the trials in Ph. 1. The other window was locked on 50% of these trials in an irregular sequence as were both windows for G. 1.

After an average of 25 trials in Ph. 1, the rats in G. 2 had developed stereotypes directed toward the 50% locked window. The rats in G. 1 had developed stereotypes after an average of 75 trials in Ph. 1, an IPP for these rats. G. 2's 100% punishment contingency at the nonpreferred window thus supported faster learning and higher overall choice performance of the stereotyped response than did G. 1's 50% punishment contingency at this window. Therefore, since other procedural factors were constant, 100% punishment was more effective than 50% punishment at this window by the pertinent criterion (Criterion 1) given earlier in S. IIA-2.5.

The figures cited above indicate that the rats in G. 2 adopted stereotypes in less than half the number of trials that the rats in G. 1 took to adopt stereotypes. Thus, the rats in G. 2 probably did not average numerically more punishments at the non-preferred window than did the rats in G. 1. The relatively greater effectiveness of G. 2's 100% punishment contingency was there-
fore probably due to the proportion per se rather than to the num-
ber of punishments at this window. Such greater effectiveness of
proportionately more punishment complements the finding cited ear-
erlier in S. IIA-1.5, that stereotypes learned during an IPP tend to
reflect avoidance of whichever window has been associated with
proportionately more punishment.

In the present experiment the proportion of fixated rats was
found to be higher in G. 2 than in G. 1. Therefore, although this
difference did not reach statistical significance, the incidence
of fixation did vary between these groups in the same direction as
did the effectiveness of punishment at the nonpreferred window.
This experiment thus adds to the evidence that fixation is more
likely with more effective punishment at the window that rats
learn to avoid in Ph. 1.

IIA-3.7. The Instrumental Model

Position trained rats may become fixated, as was mentioned in
S. IIA-3.1. However, with position training, the incidence of
fixation has consistently been found to be lower than with the
usual procedure of the Maier paradigm (e.g., Maier, Glaser, &
Klee, 1940; Maier & Klee, 1943, 1945; see also S. IIA-6.4). One
experiment showing such an effect will be described in detail in
S. IIA-6.2. Such an effect was also obtained with a third group
of rats that was position trained in the experiment (Wilcoxon,
1952) described in the preceding section. This effect involved a
comparison between Gs. 1 and 3, but it is especially revealing to
compare G. 3 with G. 2 in this experiment.

To compare the procedural contingencies between Gs. 2 and 3, the stereotyped response yielded punishment with 50% frequency for G. 2 and with 0% frequency for G. 3 in Ph. 1, whereas all other procedural factors were constant, including punishment of stereotyped responses in Ph. 2. The incidence of fixation was found to be considerably higher for G. 2 than for G. 3. Punishing the trained choice in Ph. 1 thus perpetuated the same choice in Ph. 2. Paradoxes such as this have not yet been dealt with in this chapter, and what will be called an "instrumental model" will now be offered to interpret the foregoing result. This model is based on the following two premises.

1. Choice performance stabilizes in fewer trials with a greater difference along some dimension between the alternative contingencies. Such an effect might be expected from the earlier discussion in S. IB-2.2, where it was noted that choice performance in a T-maze increases faster to its final 100% level when the parametric weight of food reward differs more greatly between the two arms of the T-maze. An analogous effect was observed in the present experiment, in which the proportion of punishments differed by 50% between the choices (50% and 100% punishment) for G. 2 but differed by 100% between the choices (0% and 100% punishment) for G. 1: As mentioned in the preceding section, stereotyped jumping developed after 25 trials on the average for G. 2, but in the case of G. 3, whose stereotyped (position trained) responses were not punished but who were otherwise subjected to the
same procedure as was G. 2, an average of only 7 trials was required for stereotypes to develop. Proportionately more punishment for the stereotyped response thus caused the alternative response to occur more times and to receive a correspondingly greater number of punishments in Ph. 1.

2. The incidence of fixation increases with increasingly effective punishment of the nonstereotyped response. In particular, since the effectiveness of this punishment can be evaluated as the number of punishments of this response, as was indicated in S. IIA-2.5, the incidence of fixation increases with the number of such punishments. The plausibility of such a relationship should be apparent from the discussion so far in this chapter.

The "instrumental model" is as follows. As a result of greater punishment of the stereotyped response, the nonstereotyped response is punished on more occasions in Ph. 1, by Premise 1. By Premise 2, the incidence of fixation increases with the number of punishments for the nonstereotyped response. Therefore, with greater punishment (or punishment vs. none) of the stereotyped response in Ph. 1, the incidence of fixation should be higher, as the case was in the present experiment. Insofar as variables pertaining to breaking and solving are positively related to the incidence of fixation, as will be discussed in S. IIA-6.5, the instrumental model applies to these variables as well as to the incidence of fixation.
The instrumental model of S. IIA-3.7 is undoubtedly an oversimplification even if it is valid, as the results of the following experiment emphasize. G. 10 of rats was trained in the usual IPP, and G. 20 was instead given position training (Maier & Feldman, 1948). Each rat in Gs. 01, 02, and 03 was given respectively 8, 16, or 24 sessions in Ph. 1. For G. 12 the procedure in Ph. 1 thus corresponded to the IPP procedure of the usual Maier paradigm.

During Ph. 2, an SPP, all the rats were manually guided to the unlocked window on every other trial. Consequently, they all broke (cf. S. IIA-3.2). Gs. 12 and 13 were found to require, on the average, more SPP trials to break than did G. 11. However, the required number of trials did not differ significantly between Gs. 12 and 13, indicating a parametric ceiling effect. The required number of trials also did not differ significantly among Gs. 21, 22, and 23. In terms of group averages, each of these three groups required fewer SPP trials to break than did any of the groups subjected to an IPP. Similarly, G. 22 required fewer SPP trials before solving than did G. 12. This effect on solving was also shown in another experiment (Maier & Klee, 1945), to be discussed in S. IIA-6.5, in which two groups were treated identically to Gs. 12 and 22 of the present experiment.
Since the results of the present experiment were not in terms of the proportion of fixated rats, these results concern fixation only indirectly. However, as was indicated in S. IIA-3.7, the incidence of fixation is generally lower after position training than after insoluble problem training. Correspondingly, in the present experiment the rats in G. 20, the position trained group, required fewer trials to break than did the rats in G. 10, the insoluble problem group. Thus, in this instance, if additional rats had received no guidance in Ph. 2, the incidence of fixation would probably have been directly related to the number of trials actually required for breaking insofar as comparisons between Gs. 10 and 20 are concerned. More generally, as will be discussed in S. IIA-6.5 and elsewhere, nonfixated rats, with or without guidance, tend to break later with treatments associated with higher incidences of fixation. Therefore, since the rats in Gs. 12 and 13 broke later than did the rats in G. 11, the incidence of fixation would probably have been greater for Gs. 12 and 13 than for G. 11 if the rats had not received guidance in Ph. 2.

Such differences might be effects of either or both of two factors that were varied but were not separated from each other in the present experiment. As the foregoing discussion intimates, one of these factors was the time between the start of Ph. 1 and the start of Ph. 2. The other was the number of punishments for stereotyped jumping in Ph. 1. For present discussion purposes the relevant factor will be assumed to have been the number of punishments for stereotyped jumping. On this assumption the present re-
sults indicate that breaking was increasingly impaired because of an increasing number of punishments for stereotyped jumping. However, since the additional punishment took place after the stereotypes had developed, this impairment of breaking was not clearly associated with an increased number of punishments for the nonstereotyped response.

Yet the instrumental model set forth in S. IIA-3.7 accounts for the effect of punishment of the stereotyped response only insofar as such punishment increases the number of punishments for the nonstereotyped response in Ph. 1. Therefore the instrumental model, even if it is valid, cannot account for the present results. What then might account for them?

To answer this question, recall from Fig. IIA-2.1 that active avoidance of shock is the general rule in Ph. 1 of the Maier paradigm. Punishment at a locked window is thus in a position to serve as a feedback stimulus in relation to shock, and, considering the findings that were discussed in Ch. 5, Part IB, a locked window would seem likely to function as such. Recall from Ch. 5, Part IB, that feedback stimuli generally become progressively more rewarding with repeated presentations. Similarly, in the Maier paradigm, a locked window might be expected to become less punishing, if not more rewarding, as the window is hit more times. Punishment learning in Ph. 2 should thus have been less for those IPP groups (Gs. 12 and 13 vs. G. 11) whose rats hit the locked window more times, because of longer training, in Ph. 1. This, essentially, was the finding indicated above.
For the rats receiving position training, on the other hand, the preferred window was consistently unlocked in Ph. 1. Hence, they would not have hit a locked window more times with longer training in Ph. 1. For them a locked window thus should not have become less capable of providing punishment after longer training. Hence, in contrast to the groups subjected to an IPP, the groups receiving position training should have been about even with each other with regard to punishment learning in Ph. 2. Accordingly, the results described above signify that punishment learning in Ph. 2 did not vary appreciably among the groups receiving position training in Ph. 1.

Though a locked window is not operationally a feedback stimulus on those relatively few trials on which escape occurs, effects analogous to feedback effects occur with escape as with active avoidance, as was discussed in S. IB-5.7. Hence, a locked window may possibly become progressively less punishing with progressively more hits regardless of whether the hits result from avoidance of or escape from the shock. In either case the foregoing argument amounts to saying that a locked window can serve as a secondary reward for a stereotyped response (cf. S. IB-10.7). Therefore, since conditioned rewards may serve as another type of secondary reward (see S. IB-10.7), it might be expected that a conditioned reward as such could likewise maintain performance of a stereotyped response. The following experiment produced such an effect and showed, in fact, that a secondary reward as such was sufficient to maintain fixation.
IIA-4.2. **Fixation as Conditioned Behavior**

The apparatus in the following experiment consisted of a start area from which two alleys branched off and then reconverged into a single goal area (Lohr, 1959). Rats were trained to obtain food in the goal box by running from the start box through whichever alley they chose. Rats in Gs. 10, 20, and 30 were shocked if they ran through one of the alleys starting respectively on the first, 251st, or 501st trial. The shock current was low for G. 01 and high for G. 02. The side with shock was the left or right side for separate subgroups within Gs. 11 and 12 each and was the preferred side for the rats in the remaining groups.

All the rats in Gs. 10 and 22 learned to choose consistently the side without shock. On the other hand, all the rats in G. 31 learned to choose consistently the side with shock. Within Gs. 21 and 32, choice performance fell into a bimodal distribution during the procedure with shock. That is, some rats learned to choose consistently the side with shock, whereas other rats learned to choose the opposite side consistently. The shock was thus a reward for some rats and a punishment for others.

In view of various findings that were discussed in Ch. 10, Part IB, the shock might have been expected to become rewarding through its position as a potential CS+ for food reward. Though the experiment did not incorporate control groups to verify that the shock developed into a reward via conditioning (cf. Ss. IA-6.1 and IA-6.2), the rats choosing the shock behaved as would have been expected with conditioning. In particular, though they tend-
ed to avoid the alley with shock on the initial trials with shock, their avoidance was inconsistent. Shock and food were conseq
tively paired with each other a number of times, and when the pairings were sufficiently numerous on the initial trials with shock, the shock became rewarding. For example, with increasingly prolonged training prior to the trials with shock, the rats' choices tended to become increasingly consistent; initial avoidance of the shock tended correspondingly to be decreasingly frequent, and shock-food pairings were thus increasingly numerous initially. Furthermore, the group differences summarized above indicate a direct parametric relationship between the number of training trials preceding the shock and the proportion of rats rewarded by the shock. The proportion of such rats was thus related directly to the number of initial shock-food pairings, as if the rewarding effect of the shock reflected conditioning that outpaced punishment learning.

As Lohr, the investigator, pointed out in regard to the present findings,

the dynamics . . . operating in this situation are analogous to those in rolling a ball toward the ridge of an incline. If the initial impetus is sufficient to carry the rat across the shock grid enough times to nullify the aversive effect, he will acquire what looks like a compulsion for taking unnecessary punishment. If, on the other hand, the impetus is not quite sufficient to carry past the critical point, he will show the normally expected complete avoidance [p. 314].

In a second experiment in the present investigation, rats were shocked on one side from the first trial on, but the shock level was gradually increased as training progressed (cf. Ss.
IB-5.1, IB-8.6, IB-8.8, IB-13.4, and IIA-8.4). Again choice performance fell into a bimodal distribution in that three fourths of the rats eventually chose the shock side consistently, whereas the remaining rats eventually chose the side without shock fairly consistently. The present investigation differed from the Maier paradigm in many ways, of course. One notable difference is that shock punishment in this investigation was contingent on a food-rewarded response, whereas punishment at a locked window is contingent on active shock avoidance or air blast avoidance that does not eventuate in food reward in the Maier paradigm.

In summary, the present results signify that a secondary reward alone may support fixation. These results thus have an important implication in view of the finding that a locked window in the Maier paradigm can also come to serve apparently as a secondary reward for stereotyped responses, as discussed in the preceding section. The implication is that a locked window, as a secondary reward, becomes progressively less punishing for a stereotyped response in the Maier paradigm and thereby fails to effectuate breaking, with fixation being the end result. This idea is consistent with the proposal set forth earlier in S. IIA-2.5, that breaking and solving occur if and only if punishment of the stereotyped response is effective enough in Ph. 2 to overbalance punishment of the nonstereotyped response in Ph. 1. In a way, the present results are ironic: For some of the rats, shock as a CS+ became rewarding apparently by being paired with food, much as food itself becomes increasingly rewarding by being paired with
certain aftereffects (cf. Ss. IB-10.2 through IB-10.4).

IIA-4.3. Absence of Punishment in Ph. 1

The previous chapter emphasized that prior punishment of a nonstereotyped response contributes to fixation, and this chapter has emphasized that punishment of a stereotyped response contributes to fixation insofar as such punishment is applied in Ph. 1. Thus, a clear prediction from the discussion so far is that fixation would be especially unlikely if neither choice response were punished in Ph. 1 of a procedure otherwise resembling that of the Maier paradigm. The findings of the following experiment confirm this prediction.

During pretraining, each rat in the experiment was trained to jump through both windows of the Lashley jumping apparatus (Christie, 1951). Upon jumping through a window, the rats gained access to food on every trial of pretraining. During Ph. 1 both windows were uncovered, and food was accessible only if a rat would jump through the window that was not chosen on the first trial of Ph. 1. Only 11% of the rats learned to jump to this window in Ph. 1.

In Ph. 2 41% of the remaining rats were given trials with the window opening blocked on the side preferred in Ph. 1, so that the rats would fall to the floor when they jumped to the window on this side. These rats all broke and solved, in contrast to the behavior in the usual SPP of the Maier paradigm. Admittedly Ph. 2 of the present experiment differed from the usual SPP in that the correct window was uncovered in this experiment. However, it has
been found that fixated rats will not break when the SPP of the usual Maier paradigm is modified in respect that the correct window is uncovered with food plainly visible through the window (Maier, 1949; cf. Wilcoxon, 1952).

IIA-4.4. An IPP Following an SPP

In the following experiment separate groups of rats were given insoluble problem training, position training, or symbol training in Ph. 1 (Maier & Klee, 1943). In Ph. 2, the SPP, rats in separate subgroups were required to make partial- or full-reversal shifts from their stereotypes. Those rats failing to solve were subsequently given guidance so that solutions then occurred.

Subsequently, in Ph. 3, all the rats were subjected to 160 trials of a typical insoluble problem procedure. Most of these rats then continued to jump consistently to the side or card to which they had been trained to jump in Ph. 2. Thus, the rats generally avoided jumping to the window at which 100% punishment had been received in the preceding SPP.

This behavior contrasts markedly with the behavior occurring when an IPP follows pretraining as in the standard Maier paradigm. Specifically, in the IPP comprising Ph. 1 of the usual Maier paradigm, rats generally require approximately 40 or 50 trials before adopting a stereotype, as was noted in S. IIA-1.5. Correspondingly, in the early part of such an IPP, rats have received numerically and proportionately fewer punishments at the eventually non-preferred window, and have received numerically fewer punishments.
at the opposite window, than had the rats in the corresponding per-
period of the second IPP, Ph. 3, of the present experiment. On all
these counts it might be expected, in view of the discussion so
far, that choice performance would have tended to remain fixed in
Ph. 3 of this experiment more than at a comparable stage of Ph. 1
in the Maier paradigm, as was observed.

In a related experiment each rat was given 20 sessions of
symbol training in Ph. 1 (Maier & Ellen, 1952). The rats in G. 1
received no manual guidance, whereas the rats in G. 2 were manual-
ly guided to the unlocked window on the 10 trials of every fifth
session of Ph. 1. In Gs. 1 and 2, respectively 64% and 90% of the
rats had learned to jump to the unlocked card by the end of Ph. 1.
Those rats that failed to learn were discarded for the rest
of the experiment. In Ph. 2 all the remaining rats were subjected
to a typical insoluble problem procedure. During this phase most
of them continued to jump consistently to the card to which they
had been trained to jump in Ph. 1. This finding accords with the
similar finding for Ph. 3 of the preceding experiment.

In the present experiment Ph. 3 was an SPP in which all the
rats were required to make partial-reversal shifts from their
stereotypes. In this phase fewer rats showed fixation in G. 2
than in G. 1 (see also S. IIA-6.5). A prior history of guidance
thus acted to prevent fixation.

This effect may have been a consequence of the reported fact
that the rats in G. 2 learned to jump to the unlocked card in few-
er trials and therefore received fewer punishments at the locked
card in Ph. 1 than did the rats in G. 1. Though this difference in punishment did not reach statistical significance, it need not have been statistically significant in order to have produced the statistically significant effect on fixation in Ph. 3. The correspondence between fixation and prior punishment provides further support for the apparent generality, discussed in the preceding chapter, that the proportion of fixated rats increases when prior jumping to the nonpreferred window has been punished on a parametrically increasing number of occasions.

IIA-4.5. Ongoing Punishment of Stereotyped Jumping

In S. IIA-4.1 an experiment was discussed in which the dependent variable was the number of trials required for breaking. Inverted, this variable could be designated "speed of breaking."

Since the parametric effects on this variable were unrelated to punishment of the nonstereotyped response in Ph. 1, as was discussed in S. IIA-4.1, speed of breaking could be considered an operational index of the effectiveness of punishment of the stereotyped response in Ph. 2. The effectiveness of such punishment might also be evaluated either in terms of jumping to a third window in Ph. 2 (cf. S. IIA-3.4) or as latency for stereotyped jumping to the locked window in Ph. 2 (see S. IIA-6.3).

All of these indices are operationally independent of any incidence-of-fixation variable. Such indices are necessary to assess whether the incidence of fixation varies inversely with the effectiveness of ongoing punishment of the stereotyped response in
Ph. 2, as was maintained in S. IIA-2.5. It should be noted, in support of this proposal, that speed of breaking generally has an inverse parametric relationship to the incidence of fixation, as was intimated in S. IIA-4.1.

If latency is to serve as an index of the effectiveness of punishment for stereotyped jumping, certain precautions are in order. The following experiment, in addition to being interesting in itself, illustrates the need for such precautions. The IPP procedure in this experiment was modified in such a way that both windows were consistently dark (Feldman & Green, 1967). During Ph. 2, an SPP, 55 v. was used to illuminate the bright window. This window was unlocked, and the dark window was locked, in Ph. 2. None of the rats solved in this phase.

In Ph. 3 the soluble problem procedure was continued as before except that the usual 120 v. was used to illuminate the bright window. The difference between the windows was thus increased along the relevant (illumination) dimension. As was noted in S. IB-3.4, such changes typically improve choice performance, and this was the case in the present experiment: About half of the rats solved in Ph. 3.

In addition, latency differentiation increased from Ph. 2 to Ph. 3 in that latencies decreased for jumps to the bright window and increased for jumps to the dark window. This increase in latency differentiation occurred quickly in Ph. 3 and might thus have represented either a stimulus-specific effect of the illumination cues (cf. S. IIA-2.3) or, conceivably, an ascending gener-
alization gradient. Alternatively, the illumination could have served as a reward for jumping (cf. S. IIA-2.3), and latency to the S+ (with the dark window on the stereotype side) could have increased secondarily.

In any case, it is uncertain whether the increase in latency differentiation represented an increase in the effectiveness of the cues as such. Therefore, since only cue effects as such could be considered synonymous with incentive effects (cf. S. IA-5.2), it is possible but not certain that the observed increase in latency differentiation represented an increase in the effectiveness of punishment on punishment trials. Yet the observed breaking and the latency increase to the dark window could all too easily be cited in support of the proposal that the incidence of fixation should vary inversely with the effectiveness of ongoing punishment of the stereotyped response. The point is this: Ongoing latencies to the locked window can be regarded as an index of the effectiveness of punishment for stereotyped jumping in Ph. 2, but only insofar as latency is considered as a function of punishment magnitude or in terms of the effects of the cues as such. Otherwise, latency may be unrelated to such punishment, as, for example, when latency varies as a function of shock intensity as described earlier in S. IIA-2.2.

Thus, in the present experiment, though the breaking in Ph. 3 was associated with a latency increase for jumps to the dark window, this association does not imply that breaking was necessarily associated with an increase in the effectiveness of ongoing pun-
ishment. In fact, breaking in this experiment might have represented a preference for the bright window (cf. S. IIA-2.3). Furthermore, if 120 v. had been used all along to illuminate the bright window, the incidence of fixation might have been higher than it was. Hence, the breaking that was actually observed may have represented a generalization decrement from Ph. 1 to Ph. 3 (cf. S. IIA-2.3) and would thus have represented a decrement in learning via earlier punishment at the nonpreferred window.

Another conceivable problem in interpreting latencies is that differentially high latencies and the accompanying differential abortive jumping in the SPP may compete with the effectiveness of ongoing punishment of the stereotyped response. That is, operationally speaking, latency and frequency of abortive jumping might be inversely related to punishment effectiveness evaluated as some variable other than latency or frequency of abortive jumping. However, such an inverse relationship has never been demonstrated, and latency presently seems to be a suitable measure of the effectiveness of punishment of stereotyped responses.
IIA-5.1. Punishment as a Treatment Parameter

Experiments with the Lashley jumping apparatus have an inherent limitation with regard to how the punishment contingency on a choice response can be varied as a treatment parameter. To clarify this point it will be helpful to digress momentarily to consider how a punishment contingency can be thus varied in behavioral experiments generally. Such a contingency can sometimes be varied in two general, separable ways (cf. S. IA-4.3), which are as follows.

1. The parametric magnitude of the punishment can be varied while the response-contingent schedule or sequence of punishments may remain constant. For example, in experiments (Karsh, 1962, 1963) that were considered in S. IB-1.3, shock as a punishment was varied in magnitude among groups of rats. However, if a rat was in one of the groups receiving shock, the rat would be shocked whenever the prerequisite response occurred. The response-contingent proportion of punished responses was thus fixed at 100%, and hence the response-contingent sequence of punishments was fixed, while the magnitude of the punishment was parametrically varied.

2. Conversely, a response-contingent schedule or sequence of punishments can be parametrically varied while the parametric magnitude of the punishment may remain constant. Such was the case,
for example, in a fixation experiment previously discussed in S. IIA-3.6, in which the punishment contingency at one window was parametrically varied as to the proportion, and hence the sequence, of trials with that window locked and was thus varied as to the punishment sequence contingent on a choice response.

The dimensions of magnitude and sequence are not entirely separable but coincide in the limiting case where a sequence of 100% punishment is compared with a sequence of 0% punishment. That is, if the punishment when administered is at a uniform magnitude in this case, the punishment could be considered constant at a positive magnitude while the proportion of punishments varies, but alternatively the magnitude of the punishment could be considered to vary, having zero and positive values, while the proportion of punishments is constant at 100%. Except for this limiting case, however, if a punishment contingency is varied along a proportion dimension with punishment magnitude constant, this variation is not synonymous with parametric variation of punishment magnitude with proportion constant.

To place the matter in perspective, it may be noted that points on one stimulus dimension may coincide with points on another in various circumstances. For example, if the loudness of a tone were at levels of zero and of a positive value, these points along a loudness dimension would coincide with points, one being zero, along a dimension of pitch or frequency. Yet in between such points variation along a pitch dimension discloses an effect, the octave effect (see S. IB-3.2), the likes of which is not seen
when sound is varied along a dimension of loudness.

Similarly, punishment variation along a magnitude dimension might reveal effects not seen when punishment is varied along a proportion dimension. In addition, punishment variation along a proportion dimension might have different effects depending on the parametric magnitude of punishment, and vice versa for punishment variation along a magnitude dimension. Such differences could be shown only if the proportion of punishments were separated from punishment magnitude in a factorial design.

Experiments with the Lashley jumping apparatus are limited in respect that punishment at a locked window cannot conveniently be varied in magnitude except in the limiting case of 100% vs. 0% punishment. Thus, among all the previously discussed fixation experiments with this apparatus, punishment at the locked windows was parametrically varied only by varying the response-contingent sequence (proportion) of trials on which the windows were locked. Punishment magnitude, on the other hand, was varied in only one fixation experiment previously discussed, in S. IIA-4.2, in which the apparatus was a branching maze. In this experiment the magnitude of punishment—shock amperage, specifically—was varied between certain groups while other treatment factors were constant, including the sequence of punishments contingent on each choice.

IIA-5.2. Punishment Magnitude in the Maier Paradigm

Since fixation may be defined in terms of punishment learning (see S. IIA-1.1), the relationship between fixation and punishment
magnitude merits scrutiny. Fortunately, despite the procedural difficulty mentioned above, there is some evidence pertaining at least indirectly to the role of punishment magnitude in the Maier paradigm. This evidence is along the following lines.

First, as mentioned in the preceding section, the magnitude and proportion dimensions overlap in the limiting case of 100% vs. 0% punishment. Thus, in this single case punishment in the Maier paradigm can be assessed as to magnitude effects by comparing performance between the Maier paradigm procedure and an identical procedure except with punishment omitted. Second, performance in the Maier paradigm can be compared among rats among whom punishment at the locked window is believed on prima facie grounds to differ in effectiveness and thus in effective magnitude. Third, although punishment of choice responses cannot readily be varied in magnitude in the Lashley jumping apparatus except as noted above, the Maier paradigm could be adapted to some other apparatus, one in which the magnitude of such punishment could be varied as a treatment parameter.

Some evidence exists along each of these three lines, and each line of evidence will be considered in turn. With regard to the first, there is no single experiment providing a comparison between the procedure of the Maier paradigm and an identical procedure except with both windows consistently unlocked. However, a tentative conclusion can be drawn from comparisons between experiments. In this connection recall the experiment, discussed in S. IIA-4.3, in which rats were never punished for jumping to either
During that experiment, as was noted, the rats developed stereotypes which they then continued to practice consistently. Thus, if performance in the Maier paradigm were compared with performance in a procedure that had both windows unlocked but otherwise conformed to the Maier paradigm, those rats never encountering a locked window would probably maintain their stereotypes until the end of the experiment. In the Maier paradigm, on the other hand, some rats abandon their stereotypes to solve in Ph. 2. In comparison to no punishment, the punishment in the Maier paradigm would thus appear to facilitate solution and hence to prevent fixation. In other words, insofar as such punishment, having a positive magnitude, is pitted against punishment with a magnitude of zero, the incidence of fixation would appear to be an inverse function of the magnitude of the punishment in both phases.

Some results of one experiment suggest that such an inverse relationship may extend to comparisons among nonzero magnitudes of punishment. In this experiment, which conformed to the Maier paradigm, administration of shock began in pretraining as described previously in S. IIA-1.3 (Feldman, 1957). By the end of the IPP, the nonfixated rats had received significantly more shocks on the average than had the fixated rats. Therefore, since the usual 30-sec. delay had preceded shock, latencies had probably averaged

1. The data considered here were originally reported by Feldman (1957) and were from an experiment by Neet and Feldman (1954), which will be brought up in S. IIA-7.7.
lower for the fixated rats. This suggests the two following possibilities.

1. On the average shock could have supported active avoidance—i.e., could have reduced latencies—more effectively for the fixated rats than for the nonfixated rats. This interpretation is problematic, however, in view of the absence of any solid rationale whereby the effectiveness of shock should be thus related to fixation. In fact, as was noted in S. IIA-2.2, one experiment showed that shock increasing parametrically in intensity was increasingly effective in reducing latencies but had no effect on the incidence of fixation.

2. As Fig. IIA-2.1 showed, punishment contingent on jumping increases latencies. Thus, in the present experiment, the apparent association between short latencies and fixation suggests that in Ph. 1 punishment at the locked windows tended to increase latencies less, and was accordingly less effective (cf. Ss. IIA-2.5 and IIA-4.5), for the fixated than for the nonfixated rats. If so, such punishment may reasonably be assumed to have been less effective in Ph. 2, as well as in Ph. 1, for the fixated rats. In effect, then, the magnitude of such punishment was possibly lower for the fixated rats than for the nonfixated rats. This possibility would suggest a normally inverse relationship between the parametric magnitude of such punishment and the incidence of fixation and thereby corroborates the foregoing inference of such a relationship. Thus, if the magnitude of such punishment were somehow varied as a treatment parameter in the Maier paradigm or
in an analogue of the Maier paradigm, and if this variation correspondingly altered the effectiveness of the punishment, proportionately more fixations would be expected with the lower magnitude of the punishment than with the higher magnitude. The findings of the following experiment confirm this expectation.

IIA-5.3. A Water-Maze Analogue of the Maier Paradigm

The apparatus in the following experiment was a water maze from which unsubmerged rats could escape by swimming through either of two channels that branched to the left and right of the start area and led eventually to a common escape ladder (Knöpfelmacher, 1953a, cf. 1953b). Unlatched doors were situated shortly beyond where the channels forked from the start area. After swimming through a door, a rat could be detained in either channel before the exit from the maze was made accessible.

On any single trial a rat would be thus detained if it swam through one door but not if it swam through the other door. In Phs. 1 and 2, the detention lasted 8 sec. for G. 10 and 80 sec. for G. 20. The detention was intended to provide punishment analogously to locking the windows in the standard Maier paradigm.

From trial to trial in Ph. 1, the detention contingency was varied irregularly between entry to the left and right channels for all the rats. On each trial in Ph. 1, both doors were simultaneously illuminated. During Ph. 2, on the other hand, only the door on the detention side was illuminated. Phs. 1 and 2 were therefore designated respectively as insoluble and soluble problem
phases in analogy to the Maier paradigm.

In Ph. 1, since the detention side was varied as indicated above, the incentive contingencies may be presumed to have differed only negligibly between the left and right responses for both G. 10 and G. 20. Moreover, recall from S. IB-2.2 that choice performance ordinarily takes more trials to reach criterion with a relatively smaller difference between the incentives. On this basis alone the rats in Gs. 10 and 20 might have been expected to require mutually about the same number of trials to develop position stereotypes. The required number of trials was in fact found to be about the same between the groups.

For G. 01 the detention side was varied irregularly from left to right in Ph. 2 as in Ph. 1. For G. 02, however, detention for any particular rat was consistently on the side to which stereotyped swimming had developed. The rats in Gs. 01 and 02 were thus required to make respectively partial- and full-reversal shifts from their stereotypes.

In summary, the procedure in Phs. 1 and 2 was largely analogous to the procedure of the Maier paradigm. However, certain differences are conspicuous in addition to the obvious difference in the response investigated. For example, both doors in the water maze were simultaneously illuminated in Ph. 1 (cf. S. IIA-2.3), and the procedure with the water maze did not provide for active avoidance analogous to shock avoidance in the Maier paradigm.

During Ph. 2 latencies on the detention trials averaged con-
siderably higher for Gs. 21 and 22 than for Gs. 11 and 12. Though this difference was not assessed statistically, it suggests that 80 sec. detention was more punishing than 8 sec. detention. This conclusion receives support from an observation that G. 21 showed significant latency differentiation in Ph. 2, whereas the observed latency differentiation for G. 11 did not reach statistical significance.

Treatment comparisons could thus be made not only between the partial- and full-reversal requirements but also between punishment magnitudes of differing effectiveness. Moreover, such comparison between punishment magnitudes could be made independently of the proportion of trials on which punishment was contingent on either choice response. In this experiment the punishment, immersion in water, continuously followed immersion prior to criterion occurrence of the target response, as the foregoing description of the procedure indicates. Recall that an analogous procedure was followed in an experiment (Church & Solomon, 1956), described previously in S. IB-12.1, in which increased shock duration following escape was of increased effectiveness as a punishment much as increased detention time can be considered to have been in Ph. 2 of the present experiment.

IIA-5.4. Fixation of Swimming

In Ph. 2 of the water maze experiment, two of nine rats broke and solved in G. 12, and no rats broke in G. 11, which also consisted of nine rats. Thus, although this difference was not sig-
significant, the trend was for more rats to break with the full-reversal requirement than with the partial-reversal requirement. For those rats that did not break in G. 12, mean latency increased as Ph. 2 progressed.

All the rats in G. 20 broke and solved in Ph. 2. Thus, between Gs. 10 and 20, proportionately more fixations occurred with 8 sec. detention than with 80 sec. detention. In other words, the proportion of fixated rats was greater with a lower than with a higher magnitude of punishment. As has been noted, the latencies in Ph. 2 indicate that the lower magnitude of punishment constituted less effective punishment. Thus, proportionately more fixations occurred with relatively less effective punishment than with relatively more effective punishment maintained throughout both Phs. 1 and 2.

This finding is particularly revealing in light of the findings previously discussed in Chs. 3 and 4, Part IB, indicating that the incidence of fixation increases with increased punishment (or, as a special case, with punishment vs. no punishment) of either choice response in Ph. 1 alone. In the present experiment, assuming that fixation was likewise related directly to punishment effectiveness in Ph. 1, the observed inverse relationship between fixation and punishment effectiveness must have been a prepotent effect whereby relatively greater punishment in Ph. 2 militated against fixation. But why should fixation have been thus related to the differential effectiveness of 80- vs. 8-sec. detention in Ph. 2 more than in Ph. 1? A logical guess would be that the 8-
and 80-sec. detention contingencies differed in effectiveness more in Ph. 2 than in Ph. 1.

A further look at the latencies bears out this idea: Though latency on detention trials was considerably higher with 80 than with 8 sec. detention in Ph. 2, as indicated above, the difference in detention times resulted in hardly any latency difference in Ph. 1. Thus, prior to breaking, the overriding effect of increasing detention time was to increase latency of the stereotyped response on detention trials in Ph. 2.

Hence, if latency on detention trials be deemed a measure of the effectiveness of detention as punishment (cf. S. IIA-4,5), the overriding effect of increasing detention time was to increase the effectiveness of detention as punishment of the stereotyped response in Ph. 2. Therefore, since proportionately fewer fixations occurred with increased detention time, the incidence of fixation was inversely related to the effectiveness of such punishment. This relationship accords with the proposal, made previously in S. IIA-2.5, that breaking and solving occur depending on whether ongoing punishment of the stereotyped response is effective enough in Ph. 2 to overbalance earlier punishment of the nonstereotyped response.

In conclusion, two important points have emerged. First, if the parametric magnitude of punishment is varied equally in Phs. 1 and 2 with each choice response being punished according to a fixed, response-contingent sequence, fewer rats become fixated when the magnitude of the punishment is relatively high than when
it is relatively low. Second, this relationship accords with the proposal that the occurrence of fixation depends on whether prior punishment of the nonstereotyped response has been sufficiently effective to overbalance punishment of the stereotyped response in Ph. 2. Thus, if fixation is "neurotic," it is at least a "rational" neurosis.

IIA-5.5. Loss of Fixation in the Water Maze

In Ph. 3 of the water maze experiment, the only subjects were those rats that were fixated at the end of Ph. 2. The procedure was the same as for Ph. 2 except that detention time was raised to 80 sec. for G. 10, the only group with fixations. In Ph. 3 six of the original nine rats broke in each group, 11 and 12, leaving three fixated rats in G. 11 and one fixated rat in G. 12 at the end of Ph. 3. All the rats subjected to Ph. 3 showed differential latencies for stereotyped responding in this phase, including those rats that did not break in Ph. 3.

In Ph. 4 the still fixated rats were manually guided to the no-detention side for a number of trials. After this procedure these rats solved. Manual guidance similarly "cured" fixations in experiments with the Lashley jumping apparatus, as already discussed in S. IIA-3.2.

Recall that G. 20 had the 80-sec. punishment contingency all along, whereas G. 10 had the weaker 8-sec. punishment contingency until Ph. 3. Also, recall that all the rats in G. 20 broke in Ph. 2 with the same 80-sec. punishment contingency that failed to ef-
fect breaking in Ph. 3 for a few rats in G. 10. Thus, although phase was a confounding factor, this difference between Gs. 10 and 20 at least suggests a direct relationship between ongoing punishment learning and prior punishment magnitude. A somewhat analogous relationship was shown in an experiment (Karsh, 1963) discussed earlier in S. IB-8.5.
IIA-6.1. Breaking and Solving in the Water Maze

The following terminology will be useful in discussing breaking and solving. The term breaking score denotes the total number of SPP trials that animals require before breaking. The term solving score denotes the total number of SPP trials that animals require before solving. The expression learning span means solving score minus breaking score. When these terms express group averages, those averages are for only those animals that break. Solving scores and learning spans do not include the 30 criterion trials for solution.

To return to the water maze experiment (Knöpfelmacher, 1953a) described in the preceding chapter, recall that the rats in G. 21 were required to make partial-reversal shifts from their stereotypes in Ph. 2, while full-reversal shifts were required of the rats in G. 22. That is, stereotyped responses in Ph. 2 yielded 50% punishment for G. 21 but yielded 100% punishment for G. 22. It was found that breaking scores in Ph. 2 averaged about twice as high for G. 21 as for G. 22. For G. 22 breaking thus occurred after about the same number of punishments rather than after the same number of trials as for G. 21.

However, average solving scores were about equal between these groups. Accordingly, breaking scores were related inversely to learning spans between these groups. Similarly, breaking
scores were negatively correlated with learning spans among the individual rats in G. 21. Thus, in Ph. 2 responses before as well as after breaking brought nonfixated rats closer to solution in G. 21.

However, breaking scores and learning spans were uncorrelated with each other within G. 22. Therefore, since every response prior to breaking yielded punishment for this group in Ph. 2, punished responses before breaking apparently failed to bring nonfixated rats closer to solution. Thus, with regard to responses before breaking, those that did not yield punishment would appear to have been those that brought nonfixated rats closer to solution.

Within G. 22 breaking scores were uncorrelated with solving scores among the individual rats. However, these two measures were positively correlated within G. 21. Therefore, although responses before breaking contributed toward solution for this group as indicated above, such responses brought nonfixated rats closer to eventual solution more slowly on the average than did responses after breaking.

A positive correlation was found between learning spans and solving scores within G. 22. In view of the above findings for G. 21, such a correlation would not be expected for G. 21, within which, accordingly, no significant correlation was found between learning spans and solving scores. Within G. 11 breaking scores were positively correlated with solving scores in Ph. 3, as was the case for G. 21 in Ph. 2.
IIA-6.2. **Breaking and Solving in the Lashley Jumping Apparatus**

An experiment with the Lashley jumping apparatus provides further information regarding effects of a full- vs. a partial-reversal requirement on breaking and solving. Certain findings of this experiment are summarized in T. IIA-6.2. These findings were not assessed statistically but are nonetheless of interest.

Note from T. IIA-6.2 that the proportion of fixated rats was lower after position training than after insoluble problem training. This result was obtained in several other experiments cited earlier in S. IIA-3.7. T. IIA-6.2 indicates also that breaking scores averaged lower after position training than after insoluble problem training but that position training relative to insoluble problem training had virtually no main effect on learning spans. Solving scores as well as breaking scores were thus lower after position training than after insoluble problem training. This finding was replicated in an experiment (Maier & Klee, 1945) to be considered in S. IIA-6.5.

Note in T. IIA-6.2 that breaking scores were greater for Gs. 11 and 21 than for Gs. 12 and 22. This effect accords with the analogous effect discussed in the preceding section in regard to the water maze experiment and, considered alone, might be taken to mean that 100% punishment per se tends to produce lower breaking scores than does 50% punishment. On the other hand, this effect might be taken to mean that breaking occurs later for rats required to jump consistently to one card than for rats required to jump consistently to one side, since most rats in Gs. 11 and 21
TABLE IIA-6.2
INCIDENCE OF STEREOTYPE FORMATION, INCIDENCE OF FIXATION, BREAKING
SCORES, AND LEARNING SPANS WITH VARIOUS PROCEDURES

<table>
<thead>
<tr>
<th>Type of Shift Required in Ph. 2</th>
<th>Training Procedure in Ph. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Insoluble problem (G. 10)</td>
</tr>
<tr>
<td>Partial reversal (G. 01)</td>
<td>8</td>
</tr>
<tr>
<td>Full reversal (G. 02)</td>
<td>9</td>
</tr>
</tbody>
</table>

Number of Rats Developing Position Stereotypes in Ph. 1<sup>a</sup>

<table>
<thead>
<tr>
<th>Partial reversal (G. 01)</th>
<th>5</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full reversal (G. 02)</td>
<td>8</td>
<td>3</td>
<td>6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Breaking Scores

<table>
<thead>
<tr>
<th>Partial reversal (G. 01)</th>
<th>86</th>
<th>34</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full reversal (G. 02)</td>
<td>18</td>
<td>9</td>
<td>48</td>
</tr>
</tbody>
</table>

Learning Spans

<table>
<thead>
<tr>
<th>Partial reversal (G. 01)</th>
<th>3</th>
<th>10</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full reversal (G. 02)</td>
<td>16</td>
<td>4</td>
<td>43&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

(Continued)
TABLE IIA-6.2--Continued

Source.--Data from Maier and Klee (1943).

Note.--The 3 x 2 procedures indicated in the headings applied to six respective subgroups each consisting of 10 rats.

a In Ph. 1 those rats that did not develop position stereotypes developed symbol stereotypes.

b For G. 32 the six rats designated as fixated were those that failed to break. However, the four rats that broke in this group did not solve but instead adopted position stereotypes. "Learning span" for these rats designates the mean number of trials from breaking until the position stereotypes were established.
were required to jump to a particular card in Ph. 2, while most rats in Gs. 12 and 22 were required to jump consistently to a particular side.

Within the boundary conditions of the present experiment, the issue can be resolved on the grounds that breaking scores were lower for G. 31 than for G. 32 as indicated in T. IIA-6.2. Also, stereotyped responses in Ph. 2 yielded 50% punishment for the rats in G. 31, and most of them—those with symbol stereotypes (see T. IIA-6.2)—were thus required to jump consistently to a particular side, while the rats in G. 32 incurred 100% punishment for the stereotyped response in Ph. 2 and were thus required to jump consistently to a particular card. Hence, it cannot be concluded that 100% punishment per se resulted overall in lower breaking scores than did 50% punishment. It appears instead that breaking occurs later for rats required to jump consistently to one card than for rats required to jump consistently to one side.

Though the full-reversal requirement in comparison to the partial-reversal requirement apparently had the main effect of decreasing breaking scores for Gs. 10 and 20, the full-reversal requirement had essentially no main effect on learning spans for these groups. However, T. IIA-6.2 suggests an interaction taking the form that the full-reversal requirement increased learning spans within G. 10. Such an effect agrees with the analogous effect discussed in the preceding section for the water-maze experiment. On the other hand, the full-reversal requirement, compared with the partial-reversal requirement, appears if anything to have
decreased learning spans within G. 20. Breaking scores and learning spans thus appear to have been inversely related to each other between Gs. 11 and 12 but to have been perhaps directly related to each other between Gs. 21 and 22.

IIA-6.3. Fixation with Full- vs. Partial-Reversal Requirements

T. IIA-6.2 indicates that proportionately more fixations occurred with a full- than with a partial-reversal requirement in Ph. 2. As far as G. 10 is concerned, this finding disagrees with the finding, mentioned earlier in S. IIA-5.4, that proportionately fewer rats became fixated in the water maze with a full- than with a partial-reversal requirement in Ph. 2. However, the effects in T. IIA-6.2 were not analyzed statistically, and the opposite finding of the water-maze experiment was not statistically significant. The best working assumption would thus seem to be that a full-reversal requirement, compared to a partial-reversal requirement, has no reliable effect on the incidence of fixation. On this assumption the discrepancy between the experiments is not a contradiction but reflects random variation.

From T. IIA-6.2 note that proportionately more rats became fixated with a full- than with a partial-reversal requirement within all three relevant groups—10, 20, and 30. That is, more rats became fixated with 100% than with 50% punishment of the stereotyped response in Ph. 2. The reliability of this finding is questionable not only for G. 10 as already indicated, but also for G. 20 in view of a finding that fewer position trained rats became
fixed with 80% than with 50% punishment, as discussed in the next section. It is granted that the discrepant findings were obtained under differing experimental conditions. Nevertheless, all things considered, it seems doubtful that the incidence of fixation differs substantially between the parametric treatments of 50% and 100% punishment of the stereotyped response in Ph. 2.

Recall the assertion in previous chapters that the incidence of fixation is inversely related to the parametric effectiveness of ongoing punishment in Ph. 2. In view of the foregoing conclusions, it follows that the effectiveness of such punishment probably would not differ much between the parametric treatments of 50% and 100% punishment of the stereotyped response in the SPP, but recall from S. IIA-3.6 that 100% punishment is more effective than 50% punishment at the nonpreferred window in Ph. 1, according to criteria discussed at the time. This apparent discrepancy can be resolved on the grounds that percent punishment in the SPP is not comparable to percent punishment in the IPP in that latency differentiation occurs in the SPP with the usual 50% punishment. Thus, whereas latency on punishment trials is probably about equal to mean latency on punishment and nonpunishment trials together in Ph. 1, latency on punishment trials exceeds mean latency in Ph. 2. Hence, latency on punishment trials is not constrained to the level of mean latency in Ph. 2 as in Ph. 1 and may thus be largely unrelated to the proportion of stereotyped responses yielding punishment in Ph. 2. Therefore, if latency on punishment trials be used to evaluate the effectiveness of punishment in Ph. 2, as in-
dicated earlier in S. IIA-4.5, the effectiveness of such punish-
ment may be largely dissociated from the proportion of punishments
for stereotyped jumping in Ph. 2. In particular, latency or pun-
ishment effectiveness may have no relationship or a weak relation-
ship to the type of shift, partial- or full-reversal, that is re-
quired.

In fact, in the presence of the cue or cues signalling pun-
ishment, stereotyped jumping yields 100% punishment regardless of
which type of shift is required. From this viewpoint it is im-
plausible that latency of punished responses would differ between
groups required to make partial- or full-reversal shifts in Ph. 2.
Apparently there are no literature reports in which latency on
punishment trials was explicitly compared between groups with dif-
ferent shift requirements in Ph. 2.

IIA-6.4. Percent Punishment in Ph. 2

The following two experiments followed a single procedure ex-
cept that Ph. 1 was a position training phase in the first experi-
ment but was an IPP in the second (Maier & Ellen, 1954, 1955).
All the rats in both experiments developed stereotyped jumping to
a particular side rather than to a particular card in Ph. 1. In
the position training experiment, the side chosen on the first Ph.
1 trial was designated as the side on which the window was to be
consistently unlocked during Ph. 1. In each experiment the major-
ity of rats developed a consistent preference for the left window.

In Ph. 2 the card with the white circle on the black back-
ground was consistently unlocked, and the card with the black circle on the white background was consistently locked. On the fifth and tenth trial of each session in Ph. 2, the locked card appeared on the stereotype side for G. 1 of each experiment, whereas on these two trials the unlocked card appeared on the stereotype side for G. 3 in each experiment. On the remaining eight trials per session, the cards were placed in the opposite manner for these groups. Stereotyped jumping thus resulted in 20% punishment for G. 1 but in 80% punishment for G. 3.

For G. 2 stereotyped jumping yielded 50% punishment in Ph. 2. For half the rats in G. 2 in each experiment, the unlocked card appeared on alternate trials on the side to which stereotyped jumping was directed in Ph. 2. For the remaining rats in G. 2, the unlocked card appeared on this side on the first five trials of each session in Ph. 2 and appeared on the opposite side for the last five trials on these sessions.

The cards were thus exchanged between the windows either one or nine times per session for G. 2 but were exchanged three times per session for Gs. 1 and 3. The punishment sequence was varied thus within G. 2 in order to ascertain whether any behavioral differences between G. 2 and the other groups should be attributed to punishment frequency or to the frequency with which the cards were exchanged. Perhaps a more direct control procedure would have been to exchange the card positions three times per session for G. 2. Anyhow, the treatment difference within G. 2 turned out not to affect the observed behavior of the rats in this group and thus
had no bearing on the observed behavioral differences among the three main groups of each experiment.

The proportion of fixated rats was found to be lower for every group given position training in the first experiment than for every group given insoluble problem training in the second. This difference is consistent with other findings, previously cited in S. IIA-3.7, that the incidence of fixation was lower after position training than after an IPP. In the first of the present two experiments, proportionately more rats were fixated in G. 2 than in Gs. 1 and 3 after position training. On the other hand, the proportion of fixated rats was lower for G. 2 than for the other two groups after the IPP of the second experiment.

IIA-6.5. Relationships Among Breaking Scores, Learning Spans, and Solving Scores

In the following experiment Ph. 1 was an IPP or a position training phase for Gs. 10 and 20 respectively (Maier & Klee, 1945). G. 01 received no manual guidance, whereas G. 02 received manual guidance to the unlocked window on alternate trials of the SPP. Breaking and solving scores were both found to be higher for G. 11 than for G. 21. Equivalent findings in another experiment were shown in T. IIA-6.2. In the present experiment solving scores were higher for G. 12 than for G. 22. This finding was replicated in an experiment already discussed in S. IIA-4.1.

In the present experiment, with breaking scores as well as solving scores being higher for G. 10 than for G. 20, learning spans were about the same between these groups. Breaking scores
also were higher for G. 01 than for G. 02. However, solving scores were about the same between these groups. Hence, learning spans were inversely related to breaking scores between Gs. 01 and 02.

The relationship between breaking scores and learning spans thus differed from one pair of main groups to the other. This difference appears not to represent a ceiling effect, since breaking scores averaged about the same for G. 10 as for G. 01 and also averaged about the same for G. 20 as for G. 02. It this appears that breaking scores and learning spans are not interrelated in any general way but that the relationship between these variables depends on the particular treatment involved.

From S. IIA-4.4 recall the experiment (Maier & Ellen, 1952) in which Phs. 1, 2, and 3 were respectively a symbol training phase, an IPP, and an SPP. Recall also that the incidence of fixation was lower for the rats receiving guidance in Ph. 1 than for the rats receiving no guidance in this experiment. In addition, both breaking scores and learning spans in Ph. 3 averaged lower for the group receiving guidance than for the group receiving no guidance. This effect did not reach statistical significance but suggests a direct relationship between breaking scores and learning spans.

In summary, it appears that breaking scores may be directly related, unrelated, or inversely related to learning spans. Thus, no general conclusions can presently be drawn about relationships between these variables. However, it does appear, tentatively,
that higher breaking scores are associated with treatments that yield higher incidences of fixation. Also, it appears tentatively that higher solving scores are associated with treatments yielding higher incidences of fixation where the incidence of fixation varies as a function of treatment differences in Ph. 1. For example, position training in Ph. 1 yields lower breaking and solving scores than does insoluble problem training, as indicated above, and position training also produces a lower incidence of fixation, as was indicated in S. IIA-3.7. The three-phase experiment just considered provides another example. An additional example will be mentioned in S. IIA-7.2.
IIA-7.1. Chlor diazepoxide Effects: The Basic Findings

Various drugs have been tested for behavioral effects with procedures conforming to or related to that of the Maier paradigm. In all the pertinent experiments, drug administration was by intraperitoneal injection. Except as noted otherwise, these experiments followed the window illumination procedure with the Lashley jumping apparatus.

Among individual experiments thus conforming to the Maier paradigm, the incidence of solution ranges between 5% and 20% for rats tested under no-drug control conditions; conversely, the incidence of fixation ranges from 80% to 95%. Pooling the results of several such experiments gives a figure of 14% solutions for 147 undrugged control rats (Feldman, 1962). As the discussion proceeds, it will be helpful to keep the 5-20% figure in mind for perspective.

Administration of several drugs has been found to alter the incidence of fixation. Such effects have been investigated to an especially great extent for chlordiazepoxide, a "minor" tranquilizer in the benzodiazepine category. In the chlordiazepoxide experiments to be described, 15 mg/kg of the drug was administered \( \frac{1}{2} \) hour before the designated sessions or \( \frac{1}{4} \) hour before each session of the designated phases, except as noted otherwise.

In one experiment chlordiazepoxide administration began after
solution and continued through the SPP, and during this time latencies increased from session to session (Feldman, 1968). Such a latency change was absent for undrugged rats that had solved. A significant Drug x Sessions interaction was thus obtained.

In another experiment chlordiazepoxide was administered in the IPP but not in the SPP for one group of rats, and 73% of them solved (Feldman, 1962). Chlordiazepoxide thus tended to prevent fixations. Chlordiazepoxide administration also decreased latencies from session to session in the IPP. In view of the aforesaid finding that chlordiazepoxide increased latencies for rats that had solved and were therefore jumping to unlocked windows, this latency reduction may have depended on the ongoing punishment at the locked windows during the IPP. In other words, this latency reduction by chlordiazepoxide suggests an interaction between punishment and chlordiazepoxide—an interaction such that chlordiazepoxide diminished the effectiveness (in this case, the latency-increasing effect) of punishment at the locked windows. Evidence supporting this idea will be considered in S. IIA-7.3.

From S. IIA-2.5 recall the proposal that the incidence of fixation should vary inversely with the effectiveness of punishment of the stereotyped response in Ph. 2. Thus, if chlordiazepoxide decreases the effectiveness of punishment at a locked window, chlordiazepoxide administration during the SPP might be expected to promote fixation. Such an effect was observed in the present experiment: Only 42% of the rats solved in a second group given chlordiazepoxide during Phs. 1 and 2 both, as opposed to 73%
for the group given chlordiazepoxide in Ph. 1 only. After 20 sessions of the SPP, drug administration was discontinued for the group given chlordiazepoxide during both phases, and the experimental procedure was otherwise continued as before. During this extended procedure an additional 27% of the rats solved in this group.

IIA-7.2. Chlordiazepoxide Effects: Supplementary Findings

In the following experiment chlordiazepoxide was again shown to impair solution. Two groups of rats were trained during a typical SPP that was not preceded by an IPP (Lewis & Feldman, 1964). In one group given chlordiazepoxide, 60% of the rats solved, whereas 93% of the rats solved in a control group not given chlordiazepoxide. In the chlordiazepoxide group an additional 13% solved when drug administration was discontinued after 20 sessions.

In another experiment rats were subjected as usual to an IPP followed by an SPP (Feldman & Lewis, 1962). In this experiment one group of rats was given chlordiazepoxide during the SPP only. Only 5% of these rats solved, and no additional rats in this group solved when drug administration was discontinued after 20 sessions of the SPP. Thus, chlordiazepoxide administration in the SPP clearly failed to promote solution.

Another experiment reproduced the finding that chlordiazepoxide administration during only the IPP decreases the incidence of fixation (Liberson et al., 1963). In comparison to other drug
treatments, chlordiazepoxide administration in the IPP also decreased breaking and solving scores and increased learning spans for nonfixated rats in this experiment. These findings accord with generalizations made earlier in S. IIA-6.5—in particular, with the generalization that lower breaking scores are associated with treatments yielding lower incidences of fixation.

Also in this experiment some rats were position trained in Ph. 1 to jump to the initially nonpreferred window. Chlordiazepoxide was administered to one group of rats during position training but not during the subsequent SPP. Proportionately fewer rats became fixated in this group than in an undrugged control group given position training in Ph. 1. However, the statistical significance of this difference was in the borderline range.

In all the aforementioned experiments with chlordiazepoxide, the drug was administered at a dose of 15 mg/kg. At doses of 5 or 10 mg/kg, however, chlordiazepoxide administration failed to affect the proportion of fixated rats (Liberson et al., 1963). As in the foregoing experiments, 15 mg/kg chlordiazepoxide during the IPP was found to reduce the proportion of fixated rats in an experiment that conformed largely to the Maier paradigm, but the stereotyped response was lever pressing rather than jumping (Lal, 1967). In this experiment the choice was between pressing one or another of two levers, and the punishment contingent on these responses was shock (see Lal, 1966).
IIA-7.3. Chlordiazepoxide-Punishment Interaction

In S. IIA-7.1, in discussing the effects of chlordiazepoxide, the assumption was made that chlordiazepoxide diminishes the effectiveness of punishment at the locked windows. It is therefore fitting to consider some evidence for this assumption. If correct, this assumption could be directly verified only with a factorial design showing that a performance difference between punishment and no-punishment (or less-punishment) treatments is smaller with chlordiazepoxide than without. Such an experiment has never been conducted with the Lashley jumping apparatus. However, the following experiment comes close.

In this experiment rats were subjected to a training procedure in which the illuminated window of the Lashley jumping apparatus was varied according to the sequence in T. IIA-1.4 (Feldman, 1968). On the odd-numbered sessions (days) the dark window was unlocked and the bright window was locked for all the rats. On the even sessions both windows were unlocked for G. 10 but were locked for G. 20. Chlordiazepoxide was not administered to any of the rats on the odd sessions or to G. 01 on the even sessions but was administered to G. 02 before each even session. The essential dependent variable of the experiment was choice performance for jumps to the dark window. This variable was assessed for odd and even sessions combined except as otherwise noted below.

Locking the windows on the even sessions had the main effect of decreasing choice performance. Though chlordiazepoxide administration had no main effect, a positive interaction was evident.
The drug thus decreased the effectiveness of locking the windows on the even sessions.

As a result of locking the windows on these sessions, choice performance not only decreased for jumps to the dark window but also increased concomitantly for jumps to the bright window. This effect per se indicates only that the locked bright window provided less effective punishment or, conceivably, more effective reward on the even sessions than did the locked dark window; the experiment was not designed to show specifically that locking the windows on the even sessions provided punishment. Presumably, however, locking the windows did provide the usual punishment. In fact, the locked bright window could be expected to have provided less effective punishment on the even sessions than did the locked dark window, the window that was unlocked on the odd sessions, since the rats made more jumps to the dark window than to the bright window on the even sessions. (However, this difference was not assessed statistically.) In short, locking the windows on the even sessions presumably furnished punishment, and therefore, since chlordiazepoxide decreased the effectiveness of locking the windows on the even sessions as noted above, the drug appears to have decreased the effectiveness of punishment.

No significant triple interaction obtained among the two treatment parameters and the factor of odd vs. even sessions. Thus, the aforementioned double interaction between these parameters did not differ reliably between the odd and even sessions. However, choice performance was higher on the odd sessions than on
the even sessions in terms of a main effect. A rationale for this effect is that increased choice performance was trained on the odd sessions only. That is, on these sessions the correct window was unlocked, and the incorrect window was locked, whereas both windows were jointly unlocked or locked on the even sessions, as has been noted. The performance difference between the odd and even sessions thus represented tonic differentiation of phasic differentiation between the configurations of the illumination cues.

The experiment demonstrated an interaction such that this performance difference occurred only for G. 02 and therefore represented differentiation between sessions with and without chlordiazepoxide. The tonic cue was thus chlordiazepoxide (cf. S. IB-3.2) rather than a temporal or session-related cue.

IIA-7.4. The Dynamics of Fixation Prevention by Chlordiazepoxide

In summary of the preceding sections, chlordiazepoxide appears to decrease the effectiveness of punishment at a locked window and, when administered in Ph. 1, prevents fixations. These effects of chlordiazepoxide seem to be more than incidentally associated with each other in view of the previously discussed findings indicating that punishment in Ph. 1 promotes fixation. A remaining question is whether fixation prevention by chlordiazepoxide is associated with a decrement in punishment effectiveness at the preferred or nonpreferred window in Ph. 1. Either possibility is plausible from the earlier discussion in Chs. 3 and 4, Part IIA. The findings of the following experiment bear on the issue.
The procedure in this experiment differed from that of the usual Maier paradigm in respect that two consecutive IPP's, of 16 sessions each, preceded the SPP (Feldman & Green, 1967). Gs. 1 and 2 received chlordiazepoxide during only the first or second IPP respectively. Within each IPP latency progressively decreased for the drugged rats and progressively increased for the undrugged rats, in agreement with a similar finding previously cited in S. IIA-7.1.

Since stereotypes presumably had developed by the end of Ph. 1, only the rats in G. 1 would have been punished at the nonpreferred window while drugged. In the SPP 41% of the rats solved in G. 1, whereas no rats solved in G. 2. This finding therefore suggests that for chlordiazepoxide to prevent fixation, rats must be drugged when they jump to the nonpreferred window of the IPP. Hence, insofar as fixation prevention by chlordiazepoxide is intrinsically associated with a decrease in the effectiveness of punishment, the critical interaction would appear to be between drug administration and punishment at the nonpreferred window, not at the preferred window, in Ph. 1.

In one experiment chlordiazepoxide was administered to respective groups of rats immediately after or one hour after each session in an IPP (Tufenkjian, 1964). Neither latencies nor the proportion of fixated rats differed between these groups and an additional group not given chlordiazepoxide. Hence, rats must be under the immediate influence of chlordiazepoxide in the IPP in order for the drug to prevent fixation.
IIA-7.5. **Effects of Drugs Besides Chlordiazepoxide**

Diazepam like chlordiazepoxide is a minor tranquillizer in the benzodiazepine category. Diazepam was administered during the IPP in two experiments with the Lashley jumping apparatus. In one of these experiments, diazepam at 5.0 mg/kg was found to reduce the proportion of fixated rats (Feldman, 1964). In the other experiment, however, diazepam at 3.0 mg/kg had no such effect (Feldman & Lewis, 1962).

In another experiment amphetamine at 2 mg/kg was administered during only the SPP (Lal, Edmonds, & High, 1967). The procedure of this experiment was analogous to that of the Maier paradigm, but the fixated response was lever pressing as in experiments that were considered in S. IIA-7.2. In the present experiment amphetamine was found to reduce the proportion of fixated rats. There are no comparable experiments in which amphetamine was administered during only the SPP of a Maier paradigm procedure with the Lashley jumping apparatus. However, in one experiment with the Lashley jumping apparatus, 1.75 mg/kg amphetamine administered during both the IPP and the SPP did not affect the incidence of fixation (Feldman & Lewis, 1962).

In another experiment with the Lashley jumping apparatus, amphetamine at 1.75 mg/kg was administered during an SPP in which rats were manually guided to the unlocked window on alternate trials (Liberson, Ellen, & Feldman, 1959). The investigators suggested that amphetamine reduced the rats' solving scores without affecting their breaking scores. However, this effect was not as-
sessed statistically and was based on a comparison between only two undrugged control rats and an unreported number of rats receiving amphetamine.

In one experiment with the Lashley jumping apparatus, the MAO inhibitor phenelzine was administered at 25-37½ mg/kg during the IPP (Bremner, 1960). Results were obtained suggesting that phenelzine decreased the proportion of fixated rats. In addition, phenelzine decreased latencies.

In another experiment a final phase, Ph. 3, followed the usual 20 sessions of the SPP (Houser & Feldman, 1971). During Ph. 3 pilocarpine and scopolamine were administered to respective groups of rats that were fixated at the end of Ph. 2. Also during Ph. 3, the rats were guided to the unlocked window on every trial on alternate sessions. Otherwise, except for drug administration, the procedure in Ph. 3 was the same as that of the preceding SPP.

On the trials without guidance in Ph. 3, the rats broke, presumably because of the guidance (cf. S. IIA-3.2). Thus, the dependent variable was not the proportion of fixated rats but was, rather, the percentage of correct responses on these trials. Though the investigators claimed to have shown significant drug effects, this conclusion is untenable in that what the authors claimed were drug effects were actually possible drug effects partially confounded with variation among the rats. To circumvent this problem the investigators should have used a "split-plot" (repeated measures) analysis or possible some logically analogous nonparametric test.
IIA-7.6. **Negative Findings**

Aside from the chlordiazepoxide, diazepam, and phenelzine experiments already cited, there have been only a few additional experiments in which the incidence of fixation was investigated as a function of drug administration during only the IPP. In these additional experiments drug administration did not affect the incidence of fixation. Negative results were thus obtained for the major tranquilizers chlorpromazine, 5.0 mg/kg (Feldman & Lewis, 1962; Feldman, Liberson, & Neet, 1957), and reserpine, .20 and .40 mg/kg (Feldman & Liberson, 1960), and for alcohol, 1.2 gm/kg (Feldman & Lewis, 1962).

Meprobamate is not a benzodiazepine as is chlordiazepoxide, but these drugs resemble each other in respect that both are minor tranquilizers and anticonvulsants, and both drugs block multineuronal spinal pathways (cf. Randall, 1961). Meprobamate like chlordiazepoxide might thus be expected to prevent fixation if administered during the IPP only. This possibility has never been investigated for meprobamate. However, meprobamate at 80 mg/kg was not found to affect the proportion of fixated rats when the drug was administered during both the IPP and the SPP (Feldman & Lewis, 1962; cf. Liberson, Feldman, & Ellen, 1959a).

By way of summary, experiments have been cited in which chlordiazepoxide, amphetamine, and meprobamate had little or no effect on the incidence of fixation when drug administration continued through both the IPP and the SPP. Similarly negative results have been obtained for other drugs likewise administered
during both phases. These drugs are chlorpromazine, 4 mg/kg (Feldman & Lewis, 1962; cf. Liberson, Feldman, & Ellen, 1959a); reserpine, .20 mg/kg (Feldman & Liberson, 1960; cf. Liberson, Feldman, & Ellen, 1959a); the MAO inhibitor iproniazid, 3.0 mg/kg (Feldman & Lewis, 1962); and phenobarbital, 25 mg/kg (Feldman & Lewis, 1962; cf. Liberson, Feldman, & Ellen, 1959a). In summary, no drug has altered the proportion of fixated rats when drug administration continued through both the IPP and the SPP, except perhaps in the case of chlordiazepoxide (cf. S. IIA-7.1).

From S. IIA-2.5 recall the proposal that the occurrence of fixation depends on whether prior punishment of the nonstereotyped response has been sufficiently effective to overbalance ongoing punishment of the stereotyped response in Ph. 2. By now it should be clear that this idea receives strong support from a variety of findings. Accordingly, a given drug effect on fixation might be related to a drug-punishment interaction that signifies a change in the balance of the effectiveness of punishment—the balance between punishment of the nonstereotyped response in Ph. 1 and punishment of the stereotyped response in Ph. 2. In particular, the drug might be expected to change the likelihood of fixation in opposite directions depending on whether the drug interacts more with punishment in Ph. 1 or in Ph. 2. Opposite effects would thus be expected depending on whether the drug were administered in Ph. 1 alone or in Ph. 2 alone.

Such opposite effects were actually shown for chlordiazepoxide, as was discussed in Ss. IIA-7.1 and IIA-7.2. The possibility
of such opposite effects implies that drug administration in both phases might produce effects that would cancel each other out. A drug effect would thus be more prominent if the drug were administered in Ph. 1 alone or in Ph. 2 alone. This idea is consistent with the fact that drug effects on fixation have been observed with drug administration in Ph. 1 only or in Ph. 2 only, whereas drug administration in both phases has generally failed to affect the incidence of fixation, as indicated above.

From the preceding section recall the experiment (Lal, Edmonds, & High, 1967) in which amphetamine administration during only the SPP reduced the proportion of fixated rats in a lever-pressing analogue of the Maier paradigm. In this same experiment 20 mg/kg desimipramine administered during only the SPP had no effect on the proportion of fixated rats. Except for a chlordiazepoxide experiment cited earlier in S. IIA-7.2, there are no reports of experiments with the Lashley jumping apparatus in which the incidence of fixation was similarly investigated as a function of drug administration in the SPP only.

However, in a related procedure with the Lashley jumping apparatus, reserpine at .10 or .40 mg/kg was administered to respective groups of fixated rats after they had completed 20 sessions of the SPP (Feldman & Liberson, 1960; Feldman et al., 1957). During the period of reserpine administration, the procedure of the SPP was continued as before. At doses of .10 and .40 mg/kg, respectively 10% and 9% of the fixated rats broke. Unfortunately, no undrugged control rats were run.
IIA-7.7. Effects of Physiological Alterations

One experiment conforming to the Maier paradigm showed the incidence of fixation to be higher for rats with frontal brain lesions than for control rats without such lesions (Smith & Feldman, 1969). Also, fewer rats solved in these two groups than in a third group in which the rats had frontal lesions and were subjected to the SPP procedure without a prior IPP. The rats with frontal lesions tended to break without solving. Such behavior is unusual in that rats that break almost always solve in the usual Maier paradigm experiments.

In additional experiments electroconvulsive shock was administered after each session of the IPP (Feldman & Neet, 1960; Liberson, Feldman, & Ellen, 1959b). During this phase latencies were found to increase progressively from session to session with this treatment while remaining essentially constant for control rats receiving no electroconvulsive shock. The proportion of fixated rats was reduced as a result of the electroconvulsive shock treatment. This effect was diminished when the shock was delayed for 5 min. after the end of each session (Liberson, Feldman, & Ellen, 1959b).

It has been suggested (Feldman & Green, 1967) that fixation prevention by electroconvulsive shock was due to retrograde amnesia in the preceding experiments, on the grounds that an apparent amnesic effect of electroconvulsive shock has been shown in other experiments. This interpretation is consonant with the point made earlier in §. IIA-2.2, that fixation represents learning carried
over from the IPP to the SPP. In an additional experiment in which the SPP procedure was continued beyond the usual 20 sessions, electroconvulsive shock administered between the 20th and 21st SPP sessions did not alter the incidence of fixation following the 20th SPP session (Neet & Feldman, 1954). Further experiments showed that electroconvulsive shock administered between the IPP and the SPP did not alter breaking and solving scores, either with guidance by means of a plexiglas screen (Feldman & Neet, 1954), or without guidance and after an 8- or 12-session IPP (Feldman & Neet, 1957).
Chapter 8

PUNISHMENT SUPERIMPOSED ON PRIOR TRAINING

IIA-8.1. Impaired Reversal After Food-Reward Training with Shock

In Chs. 3 and 4, Part IIA, it was repeatedly indicated that fixation becomes more likely with increased punishment of either or both choice responses in Ph. 1. Also, in S. IIA-6.5, it was indicated that higher breaking and solving scores are associated with higher incidences of fixation, at least in cases where the incidence of fixation varies as a function of treatment differences in Ph. 1. Breaking and solving scores, or some analogue thereof, might thus be expected to increase with punishment—compared to no punishment—of both choice responses in a prior phase, even if fixation is absent. Such an effect was shown in the following experiment (cf. Farber, 1954).

In Ph. 1 food was placed in one of the goal boxes in a T-maze, whereby all the rats were trained to choose the T-maze arm leading to that goal box (Farber, 1948). For G. 10 the procedure in Ph. 2 was simply a continuation of the procedure in Ph. 1, whereas the procedure for G. 20 differed in one respect: Regardless of the side chosen, the rats in G. 20 were shocked between the choice point and the goal box on every trial of Ph. 2. The rats in G. 20 were shocked also in the stem of the T-maze if they did not go to one of the arms within a given period of time. They were thus constrained to make a choice on every trial of Ph. 2. Though the procedure for G. 20 produced a decline in choice per-
formance initially in Ph. 2, choice performance soon recovered. All the rats thus were running consistently to the side with food by the end of Ph. 2.

In Ph. 3 G. O2 alone was given two 10-min. feeding sessions at the previous site of shock in the arm that had led to food. Subsequently, in Ph. 4, all the rats were given reversal training in the T-maze, with food now being on the side opposite to where it had been in Phs. 1 and 2. No shock was administered in Ph. 4.

The criterion for reversal learning was two consecutive choices of the goal box with food in this final phase. Reversal learning in the present experiment may thus be considered to have been somewhat analogous to breaking or solving in a paradigmatic fixation experiment. A notable difference between this experiment and the usual fixation experiment is that the incorrect response was unpunished in the final phase of the present experiment. The results described below for the present experiment thus cannot be interpreted in terms of secondary reward effects of ongoing punishment, as were the results of certain fixation experiments considered earlier in Ch. 4, Part IIA.

On the average, reversal of the originally learned choice response took about four times as many trials in Ph. 4 for G. 21 as for G. 22. For G. 22, in turn, reversal took about 1½ times as many trials as for Gs. 11 and 12 each. The essential findings of this experiment were confirmed in a later experiment, in which two additional findings of interest were also obtained (Moltz, 1954). First, confinement at the site of shock facilitated subsequent re-
versal as much as did the feeding there in Ph. 3. Second, when
the maze color differed from Ph. 2 to Ph. 3 at the site of shock
and then of feeding, feeding in Ph. 3 facilitated subsequent re-
versal less than when the maze color did not differ thus.

In summary, the two preceding experiments indicate that re-
versal learning for an unshocked choice response is retarded as a
result of a previous shock contingency on both choice responses
during acquisition training. The instrumental model of S. IIA-3.7
seems applicable here. Additionally, feeding or confinement in
Ph. 3 had an effect that may have represented latent learning.
That is, in view of the experiments that were discussed in S.
IB-13.1, G. 22's performance during reversal training should have
tended to be as if conditions at the shock site had been the same
during acquisition as during the subsequent feeding or confinement
phase. In particular, G. 22's performance during reversal train-
ing should have tended toward being the same as if the shock had
not been given in acquisition training. Thus, between Gs. 12 and
22, the shock effect on reversal should have been reduced in com-
parison to the shock effect between Gs. 11 and 21, as the case
was.

IIA-8.2. Enhanced Reversal After Food-Reward Training with Shock

Though the preceding experiments demonstrated impaired rever-
sal learning after food-reward training with shock, the following
experiment disclosed an opposite effect. This experiment was
based on the shock-right paradigm that was discussed in Ss.
IB-10.6 through IB-10.8. In Ph. 1 rats were given four trials per session, in which the first trial was a free-choice trial (Fowler & Wischner, 1969). On the other three trials, each rat would be forced to respond so that it went to the left-bright, right-bright, left-dark, and right-dark sides each on one trial per session. In Ph. 1 the rats in G. 10 were not shocked, whereas the rats in G. 20 were shocked for making the correct response. The parametric illumination difference between the goal boxes was the same as that for which no shock-right facilitation occurred in an experiment (Fowler & Wischner, 1965) discussed previously in S. IB-10.7. In the present experiment, correspondingly, free-choice performance did not differ between Gs. 10 and 20 in Ph. 1.

In Ph. 2 all the rats were given reversal training, with food now on the side opposite to where it was in Ph. 1. Free-choice responding was permitted on all the trials in Ph. 2. During this phase the rats in Gs. 01, 02, and 03 were respectively not shocked, shocked for the previously incorrect response, and shocked for the previously correct response.

Performance of the newly correct response was greater for G. 20 than for G. 10 and was greater for G. 03 than for Gs. 02 and 01, whose performances were about equal in Ph. 2. No interactions were evident. Thus, for G. 21 in comparison to G. 11, when the trained choice response yielded shock in Ph. 1, reversal learning without shock was facilitated in Ph. 2.

The apparent discrepancy between this finding and the T-maze findings previously discussed is probably related to the fact that
shock was contingent on only the correct response during acquisition training in the present experiment, whereas shock was simultaneously contingent on both choice responses in the experiments discussed previously. Thus, whereas the instrumental model accounts for the results considered in the previous section, this model does not apply to the present experiment. In addition, the present experiment differed procedurally from the experiments described in the preceding section with respect to the forced-choice procedure in the present experiment, and in respect that shock was introduced at the start of the present experiment.

IIA-8.3. Extinction of Previously Punished Responses

In virtually all the experiments considered so far in Part IIA, animals had a choice between alternative responses. The instrumental model of S. IIA-3.7 was proposed in reference to such situations. This model might, however, extend to situations where the "choice" is between occurrence and nonoccurrence of a single response such as a runway response.

For example, consider a training procedure whereby punishment is presented contingently on a given response's nonoccurrence within a criterion time interval and thereby supports active avoidance. If occurrence of this response also yields punishment, then this response-contingent punishment, by retarding performance, might tend to increase the number of punishments for nonoccurrence of this response. Thus, by reasoning analogous to that whereby the instrumental model has been applied, such response-
contingent punishment in acquisition training might impair later reversal from occurrence to nonoccurrence of the trained active-avoidance response—might, in other words, impair extinction of active avoidance.

The foregoing example presumes that an identified punishment is contingent on nonoccurrence of the target response. However, nonoccurrence of that response may yield no identified punishment and yet may still yield some unidentified punishment, punishment that the experimenter does not administer deliberately and of which he is unaware, in which case the aforesaid mechanism would still apply. Response-contingent punishment in acquisition training then would still retard extinction.

For example, such punishment might retard extinction of a response that is acquisition-trained with reward rather than as an active avoidance response. In other words, if reward supports acquisition of a response that yields punishment along with the reward, performance during extinction training might be greater than it would be if such punishment were omitted. The following experiments revealed such effects.

IIA-8.4. Extinction of Previously Punished Runway Responses

During acquisition training in one experiment, rats were trained to run down a runway for food reward, and, in addition, some of the rats were shocked in the goal box (Martin & Ross, 1964). During subsequent extinction training, neither food nor shock was presented in the runway apparatus. During the first few
sessions of extinction training, response speed in the goal area was higher for the rats that had been punished (shocked) than for the previously unpunished rats. However, response speed subsequently converged for the separate groups.

In another experiment rats in G. 1 received food reward on each acquisition training trial in a runway (Logan, 1960). Rats in G. 2 received food reward without shock on 50% of the acquisition training trials and received food reward with shock on the remaining 50% in an irregular sequence. The procedure for G. 3 differed in respect that no food reward was given on those trials with shock. Rats in G. 4 received food reward with shock on all the trials of acquisition training. During extinction training, neither food nor shock was presented in the runway apparatus.

Among the rats receiving consistent reward (those in Gs. 1, 2, and 4), response speed in acquisition training decreased parametrically with an increasing proportion of trials with shock. Thus, although shock administration took place just before a rat would reach the food, there was no evidence that the shock served as a secondary reward as in various experiments that were described in Chs. 5 and 10 in Part IB. In fact, the rats in G. 4 stopped running altogether during acquisition training. Consequently, no extinction data were presented for them.

Among the three other groups, resistance to extinction was greatest for G. 3 and least for G. 1. The data for G. 3, however, were not explicitly compared with the data for Gs. 1 and 2 in the original report, and thus the difference between G. 3 and Gs. 1
and 2 is only suggestive. However, G. 3 alone among these groups showed no sign of extinction.

In Ph. 1 of another runway experiment, the rats in each group received food reward on 50% of the trials in an irregular sequence (Brown & Wagner, 1964). No shock was given on these trials. On the remaining trials in Ph. 1, G. 10 received food reward and no shock, G. 20 received neither food reward nor shock, and G. 30 received food reward followed by shock when the rat had eaten the food. The intensity of the shock was gradually increased from 75 to 235 v. as acquisition training progressed (cf. Ss. IB-5.1, IB-8.6, IB-8.8, IB-13.4, and IIA-4.2).

During Ph. 2 neither food nor shock was presented in the runway apparatus for G. 01. This group thus received ordinary extinction training. The rats in G. 02 received food reward on all the trials in Ph. 2 and consistently received 235 v. shock after eating the food. The consistent Ph. 2 procedures for Gs. 01 and 02 thus corresponded to the respective procedures for Gs. 20 and 30 on some trials of Ph. 1.

On the last day of training in Ph. 1, response speed for G. 20 was slightly lower than for G. 10 and was substantially higher than for G. 30. From session to session, response speed progressively decreased in Ph. 2 for all the groups except G. 32, for whom response speed remained essentially constant in Ph. 2. On the last session of Ph. 2, response speed was greatest and mutually equal for Gs. 21 and 32. Response speed in this session was greater for G. 22 than for Gs. 12 and 31, whose response speeds
were about equal to each other on this session. Response speed was least for G. 11 on this last session.

In comparison with G. 01, the greater final performance for G. 02 indicates that extinction for G. 01 was more marked than was passive avoidance for G. 02. In comparison with G. 11, the greater terminal performance for G. 31 accords with the findings of the preceding experiments. The final performance difference between Gs. 12 and 32 may have been of a related nature and also, it should be noted, represents a contrast effect of the sort discussed earlier in S. IB-8.5. In comparison with G. 11, the greater terminal performance for G. 21 represents a typical partial reinforcement extinction effect of the sort that was discussed in S. IB-4.1.

IIA-8.5. Facilitatory Prior Punishment as an Interactive Factor

Besides those experiments discussed above, additional experiments have shown that punishment superimposed on acquisition training enhances performance during subsequent extinction training without the punishment (e.g., Karsh, 1964). However, if the punishment totally suppresses performance in acquisition training, then during extinction training the previously punished animals' performances cannot be thus enhanced--cannot remain at or decrease to a level above the concomitant performance level for the previously unpunished control animals. By extension, even if punishment in acquisition training suppresses ongoing performance incompletely, this suppression may be so pronounced as to preclude en-
hancement of the punished animals' performances during the subsequent extinction training without the punishment. Such enhancement could thus result only from punishment that is weak enough or counterbalanced by enough reward to produce only mild suppression in acquisition training. Such enhancement might thus reflect an interaction between the punishment factor and the factor of counterbalancing reward in acquisition training. Such an interaction was shown in the following experiment.

Gs. 10 and 20 of rats received food reward on two different VI schedules, with G. 20 receiving the more frequent reward (Church & Raymond, 1967). G. 02 alone received shock contingent on lever pressing. During this procedure lever pressing rate was higher for G. 20 than for G. 10 and was lower for G. 02 than for G. 01. During subsequent extinction training, neither food nor shock was presented. In terms of lever pressing rate in extinction training, a positive interaction was obtained among the groups.

The results of the following experiment appear related in principle to the results discussed in this and the preceding sections. Gs. 1 and 2 of puppies each received an equal number of daily sessions during which they were petted and fondled when they approached the experimenter (Fisher, 1955). The animals in G. 2 concomitantly received additional daily sessions in which they were shocked, switched, and handled roughly when they approached the experimenter. Each animal's performance was measured as the amount of time that the animal spent near the experimenter in any
given session. On extinction-training sessions the experimenter sat quietly and did not shock, switch, or handle the animals. Performance on these sessions was higher for G. 2 than for G. 1. This difference suggests that extinction of the approach response was impaired for G. 2, though the findings were not reported in sufficient detail to allow definite conclusions.

IIA-8.6. Impaired Extinction, Contrast Effects, and Fixation

The findings of the preceding sections elucidate the nature of contrast effects and of fixation. From the earlier discussions in Ss. IB-8.5 and IB-13.5 and elsewhere, contrast effects appear to have an intrinsic direct parametric relationship to enhancement of acquisition performance—enhancement relative to performance diminished through either reduced reward or superimposed punishment. A contrast effect in converse would thus be related to a reduction in acquisition performance. Extinction impairment as described in the preceding sections is likewise associated with a reduction, via punishment, of acquisition performance and differs in only one essential way from such contrast effects in converse: Whereas contrast effects—ergo, contrast effects in converse—occur when the performance-reducing treatment of the acquisition training phase continues or is introduced for respective groups in the subsequent phase, extinction was impaired without application of the performance-reducing treatment, namely punishment, in the second (extinction-training) phase.

Thus, while contrast effects attend the factor of introduc-
tion vs. continuation of punishment in the second phase, equivalent effects can occur without punishment in Ph. 2. That is, such effects apparently depend not on this factor per se but rather on the accompanying factor of no punishment vs. punishment in Ph. 1. Thus, where this factor is involved, contrast effects in converse seem to be only special instances of the effect of punishment vs. no punishment in Ph. 1, other instances of which are the extinction impairment effects considered in the preceding sections.

As special instances of such effects, contrast effects in converse can be interpreted in terms of the instrumental model just as extinction impairment through such punishment was interpreted in S. IIA-8.3. Such contrast effects in converse amount to secondary reward effects of punishment, as the earlier discussion in S. IB-8.5 would indicate. The instrumental model thus accounts for secondary reward effects of punishment.

So a crucial point emerges: Insofar as fixation represents a secondary reward effect of punishment as indicated earlier in Ch. 4, Part IIA, the instrumental model can account for fixation. In that chapter it was noted that fixation cannot entirely be explained by the instrumental model as it was applied in Ch. 3, Part IIA. Now, however, it can be seen that fixation can be more fully explained by the instrumental model as it has been more broadly applied in the present chapter.

The contrast effects and extinction-impairment effects that have been under consideration may be summarized as follows: The treatment variable was a contingency in Ph. 1--a contingency on
the response that was trained in Ph. 1—and the effects of this
variable were such that impaired performance in Ph. 1 foreshadowed
enhanced performance with the retraining procedure—e.g., the extin-
tion training procedure—in Ph. 2, barring floor and ceiling
effects. Analogously, insofar as punishment of a trained (stereo-
typed) choice response impairs choice performance of that response
in Ph. 1 of a representative fixation experiment, enhanced choice
performance of that response ensues as fixation with the retrain-
ing procedure of Ph. 2 if additional factors that would oppose
this effect are inoperative (see S. IIA-3.7 and Ch. 4, Part IIA).

An apparent generality thus emerges: Insofar as performance
of a response is a function of a contingency on that response in
initial training, performance during this initial training has an
inverse parametric relationship to performance with a subsequent
retraining procedure. As indicated above and in Ss. IIA-3.7 and
IIA-8.3, the instrumental model can account for such inverse rela-
tionships. Besides those cases considered above, another case of
such an inverse relationship is the partial reinforcement extinc-
tion effect that was described in S. IB-4.1.

As has been indicated, such inverse relationships obtain
where occurrence of a target response fulfills the contingency
that serves as the treatment factor varying in Ph. 1. However,
the opposite type of relationship—a direct relationship—seems to
apply in the case of active avoidance, whereby nonoccurrence of a
target response fulfills such a contingency. In some shuttlebox
experiments, for example, dogs quickly trained to avoid very in-
tense shock were found to maintain their avoidance performance unabated for hundreds of trials of extinction training (see Solomon & Wynne, 1954).

IIA-8.7. Extinction of Active Avoidance

In the experiments that were just noted, enhanced active avoidance in acquisition training foreshadowed impaired extinction manifested as enhanced performance of the avoidance response in extinction training. Correspondingly, if active avoidance is sufficiently enhanced, the punishment supporting the active avoidance is thereby not presented on certain trials of acquisition training. In effect these trials thus constitute extinction training. In this sense extinction training may begin sooner, and acquisition training may thus be shorter, with relatively enhanced acquisition in the form of active avoidance. Recall from S. IB-13.5 that relatively short acquisition training may result in relatively slow or poor extinction (cf. S. IB-13.6) through an effect allied to latent learning. Poor extinction might thus be expected to accompany enhanced acquisition with respect to active avoidance, as has been noted to be the case.

Besides an effective curtailment of acquisition training, another type of factor may retard extinction of active avoidance in particular. Suppose that an animal is punished at time \( t_1 \) and again at time \( t_2 \). The time interval \( t_2 - t_1 \) might then become an avoidance acquisition cue, \( (t_2 - t_1)^+ \). Temporal cues of a similar nature were discussed in S. IB-4.4. Once having reached an inter-
val of duration $t_2 - t_1$, the time interval starting at $t_2$ would exceed that duration to a progressively greater extent and might be expected therefore to follow a descending generalization gradient in maintaining avoidance. Finally, an interval $t_3 - t_2$ might be reached that would be sufficiently ineffective as a cue so that the animal would fail to avoid the punishment. This interval would thereupon become an additional acquisition cue, $(t_3 - t_2)^+$. As the process was then repeated, progressively longer time intervals since punishment would continue to be added to the repertoire of effective cues. Hence, avoidance would fail with decreasing frequency, and extinction of the avoidance response would thus become less feasible. There is some evidence that would favor the foregoing interpretation (see Denny & Dmitruk, 1967; cf. Capaldi, 1967).

Parametrically, with relatively enhanced avoidance acquisition through relatively strong punishment, a relatively large number of punishments would be avoided. Thus, the process described above would correspondingly be relatively advanced at any given stage of training, and the capacity for extinction would therefore be relatively impaired. Hence, with relatively enhanced acquisition of avoidance, extinction would be relatively impaired. Such a relationship would accord with the empirical evidence indicated above, and the postulated mechanism thus accounts for the pertinent data.

To round off the picture, it should be noted that enhanced acquisition usually presages enhanced extinction when escape via
a given response is compared with active avoidance via that response, with comparable stimulus intensities. In one experiment, for example, asymptotic runway response speed in acquisition training was higher, and extinction was faster, for rats trained to escape shock than for rats trained to avoid shock (Bender & Melvin, 1967). This difference was for rats given ordinary extinction training without shock, though additional rats were shocked during extinction training, as mentioned when this particular experiment was considered earlier in S. IB-5.2.

As a general rule, asymptotic response speed is higher with escape training than with active avoidance training with comparable stimulus intensities. Such a difference was found, for example, in two of the experiments (Beecroft & Brown, 1967; Seward & Raskin, 1960) that were discussed in Ch. 5, Part IB. Correspondingly, several experiments have shown extinction to be faster after escape acquisition than after avoidance acquisition (Jones, 1953; Santos, 1960; Sheffield & Temmer, 1950). Also, after a typical escape acquisition phase in which the drive was presented on every trial, extinction was found to occur more readily than after an acquisition phase in which the drive was presented only on intermittent trials (Jones, 1953) (cf. S. IB-4.1). Perhaps the better extinction after escape training than after active-avoidance training reflects a generalization decrement in escape—a decrement due to the change in drive (e.g., shock) magnitude (from positive to zero) between acquisition and extinction. As was noted in S. IB-3.2, such decrements can occur with magnitude changes
in drives as well as cues.

IIA-8.8. The Dilemma of Extinction of Avoidance

Active avoidance of relatively severe punishment has been noted to undergo extinction relatively poorly. Performance in extinction training is thus commensurate with the level of punishment supporting the antecedent acquisition and thus represents an appropriate accomodation to a dilemma that Hull (1929) described as follows.

If experimental extinction [of avoidance] operates fully the organism seems doomed to suffer the injury of the noxious stimulus periodically in order to renew the strength of its [trained] defense reactions. If, on the other hand, experimental extinction does not operate, the organism seems doomed to dissipate much of its energy reacting defensively to irrelevant stimuli [p. 510].

In the case of passive avoidance, strong enough punishment would decrease performance to the point of eliminating responding altogether, and in the absence of responding, the Darwinian response variation required for training would be absent (cf. S. IA-4.6). Hence, strong enough punishment in acquisition training might preclude extinction training, and extinction thus could not occur. More moderate punishment, however, might decrease performance without eliminating responding, in which case extinction could occur. Thus, like extinction of active avoidance, extinction of passive avoidance would represent an accomodation appropriate to the severity of the punishment supporting acquisition.

Similarly, where fixation is concerned, its incidence is com-
mensurate with the severity or effectiveness of the punishment that was avoided through stereotyped responding in Ph. 1, as was indicated in Ch. 3, Part IIA. Fixation like simple avoidance thus represents an appropriate accommodation to a dilemma like that which Hull described. Still, however, the dilemma remains, for persistent avoidance and fixation still represent behavior that fails to adjust to the ongoing conditions of extinction training or of reversal training in an SPP.

How may the dilemma be resolved; how may such training be accomplished? In the case of fixation, two ways have been discussed: manual guidance (see Ss. IIA-3.2 and IIA-5.5) and increased punishment of the stereotyped response in Ph. 2 (see Ss. IIA-5.4 and IIA-5.5). Similar treatments might aid extinction of simple active or passive avoidance. The following experiment illustrates an additional type of treatment whereby extinction may be facilitated.

In Ph. 1 rats in Gs. 10 and 20 were trained to obtain food reward in respectively black and white runways (Berkun, 1957). Once the runway response was trained, each rat was shocked as it put its nose into the food cup. After the rats had thus been trained not to approach the food, they were given continued training in Ph. 2 without shock being contingent on the trained runway response. In Ph. 2 food was still available for some rats but not for others in each subgroup. For G. 01 training in Ph. 2 was in the same runway as was used in Ph. 1. However, training in Ph. 2 started with the white and black runways respectively for Gs. 12
and 22.

Performance recovery time was measured as the number of runway trials that a rat would require before responding again. After performance recovered for any rat in G. 02, the rat was further trained in a gray runway. Then, after performance recovered in the gray runway, the rat was run in the same runway as was used in Ph. 1.

Average recovery time was 12.6 trials for G. 01 (in the same runway as was used in Ph. 1) and was 9.4 trials for G. 02 in the first runway used in Ph. 2. Generalized passive avoidance thus underwent extinction faster for G. 02 than did nongeneralized passive avoidance for G. 01. In the second and third runways used in Ph. 2, average recovery time was respectively 3.0 and 2.6 trials for G. 02. Therefore, since the third runway was that used in Ph. 1, recovery time in that runway was faster for G. 02 than for G. 01.

Thus, for G. 02, extinction of generalized passive avoidance generalized, itself, from one runway to the next in Ph. 2, and this generalization aided extinction in the runway that had been used in Ph. 1. Conceivably such a process could have reduced total recovery time, though total recovery time in this experiment was greater for G. 02 (9.4 + 3.0 + 2.6 trials) than for G. 01 (12.6 trials). The present results were confirmed and extended in a later experiment (Taylor & Maher, 1959). Perhaps a recovery procedure like that described above might serve to break fixations in the Maier paradigm.
Part II

FIXATION OF BEHAVIOR

B. FIXATION IN MICE

(Original research)
Chapter 1

PURPOSE AND METHOD OF THE RESEARCH

IIB-1.1. A Fixation Experiment

An experiment was conducted with a two-phase procedure for demonstrating fixation. The general nature of such procedures was outlined in S. IIA-1.1. One purpose of the present experiment was to assess the experimenter's contention that fixation ought to be directly associated with the number of punishments of the choice that is incorrect in Ph. 1. Evidence for such an association was considered in Ss. IIA-3.1 through IIA-3.4 (cf. S. IIA-2.5).

Such an association can account for paradoxical effects in earlier experiments, as was indicated in Ss. IIA-3.1 and IIA-3.7 (cf. S. IIA-1.1). The present experiment was designed to establish the occurrence of such an association in conjunction with a paradoxical enhancement of fixation. Latencies in Ph. 2 were assessed to rule out the possibility that the observed fixations might reflect insensitivity to punishment in Ph. 2.

In the present experiment it was anticipated that one of the two planned treatments might result more nearly in a 50% incidence of fixation than would the other. As a control procedure the procedure resulting more nearly in 50% fixations would obviate the possibility of floor and ceiling effects obscuring the effect of any comparison procedure that might be used in subsequent experiments. In the present experiment the procedure yielding closer to 50% fixations would thus be shown to be the better standard con-
trol procedure for various anticipated future experiments con-
cerned with treatment factors other than that of the present ex-
periment. One purpose of the present experiment was thus to serve
as a pilot experiment.

IIB-1.2. Subjects

Ten male mice were used in each of the following genera and
strains; the indicated weights were obtained at the start of pre-
training (cf. S. IIB-2.2): Mus musculus domesticus C57Bl/6J
(black mice), 20-24 gm., obtained from Roscoe B. Jackson Memorial
Laboratory, Bar Harbor, Me.; Mus musculus domesticus CF-I (white
mice), 31-38 gm., obtained from Carworth Farm, Portage, Mich.; Mus
musculus "Missouri" (so-called gray mice, actually colored brown),
22-25 gm., obtained from a private source; Microtus ochrogaster
(meadow voles), 33-46 gm., obtained from the same private source;
Onychomys leucogaster (grasshopper mice, also called Onychomys
torridus), 36-40 gm., obtained from The Pet Corral, Tuscon, Ariz.;
and Peromyscus maniculatus Bairdii (deer mice), 15-19 gm., de-
scended from mice obtained from Roscoe B. Jackson Memorial Labora-
tory.

Mus m. C57Bl/6J and Mus m. CF-I are inbred laboratory
strains. The Mus m. "Mo.," Microtus, and Onychomys subjects were
caught in the wild by trappers. The Peromyscus subjects were re-
cent descendants of mice trapped in the wild. Onychomys is a des-
ert mouse, whereas Mus m. "Mo.," Microtus, and Peromyscus are

1. Forrest D. Lovan, Steelville, Mo.
grasslands mice. *Mus* belongs in Family Muridae, which includes rats as well, whereas *Microtus*, *Onychomys*, and *Peromyscus* are in Family Cricetidae, which includes also gerbils, hamsters, muskrats, and lemmings. Both families are subsumed under Order Rodentia, Suborder Myomorpha.

The several genera and strains were used in the hope that taxon-related behavioral differences in the present experiment could be related to other differences among the taxa. Investigations by this laboratory showed such differences with regard to the following: ontogeny (Scudder, Karczmar, & Lockett, 1967); learning (Karczmar & Scudder, 1969; Scudder, Avery, & Karczmar, 1969); effects of pemoline magnesium hydroxide on learning (Karczmar & Scudder, 1969); ethological behavior (Scudder, Richardson, & Karczmar, 1969), including aggression (Karczmar & Scudder, 1967; Scudder, Richardson, & Karczmar, 1969); "intelligence" and "curiosity" (Karczmar & Scudder, 1969); motor activity (Karczmar & Scudder, 1967); electroshock latency and endogenous brain levels of dopa, norepinephrine, dopamine, and serotonin (Scudder et al., 1966); endogenous brain levels of acetylcholine (Sobotka, Scudder, & Karczmar, 1968); acetylcholinesterase activity (Karczmar, Sobotka, & Scudder, 1968); and neuroanatomy and neurohistological distribution of acetylcholinesterase in the brain (Betti, 1969). All the mice in the present experiment were housed in male-female pairs under a 14-hour light cycle and with ad-lib food and water.
IIB-1.3. The General Design of the Apparatus

The experimenter designed and built the apparatus specifically to accommodate the mice used in the present research. The apparatus resembled the Lashley jumping apparatus (cf. S. IIA-1.2) but unlike the Lashley jumping apparatus was designed so that animals could be enclosed within it, since the wild mice could otherwise have escaped easily. Enclosed containers were used for transporting mice between parts of the apparatus.

The apparatus consisted basically of a "grid compartment" from which a mouse could jump to either of two windows. The floor of this compartment consisted of a grid of 18 bus bar wires, 1/16 in. in diameter, with 1/8 in. spaces between wires. The grid could supply electric shock from the scrambling device shown in Fig. IIB-1.3.

This device worked in such a way that a mouse would be shocked whenever it closed the secondary transformer circuit shown in Fig. IIB-1.3. The shock was "scrambled" in that application of a differential voltage was constantly being shifted from one grid wire to another when the SPST switches in Fig. IIB-1.3 were closed (see Fig. IIB-1.3). Without such scrambling the mice could easily have avoided the shock by remaining motionless on grid wires of equal voltage. The purpose of the scrambler was to preclude such avoidance.

The grid compartment was open at the top and on the front side, the side toward the windows, but was enclosed on the back side and on the lateral sides by 3/8 in. thick transparent plexi-
Fig. IIB-1.3. The shock scrambler. Closing the left-hand SPST switch activates a 72 r. p. m. motor. Each revolution of this motor produces one revolution of a rotary switch. When the left-hand SPST switch is closed, closure of the right-hand SPST switch activates a time-delay relay which, when closed, delivers current to a transformer. The secondary coil of the transformer then supplies power to the rotary switch in such a way that one pole of the rotary switch is at a different voltage than are the remaining 17 poles. Therefore, because each pole of the rotary switch is connected to one grid wire, one grid wire correspondingly has a different voltage than do the remaining 17 grid wires. Each grid wire in turn becomes differentially charged in this way as the rotary switch turns. The experimenter built the scrambler.
The inside of the grid compartment was 3 3/8 in. long, 3 in. wide, 3 7/8 in. high from the grid to the open top, and 7/8 in. high under the top surface of the grid. Surrounding and parallel with the front side of the grid compartment was the back wall of what will be called the "outer front compartment," which extended forward away from the grid compartment. This wall was made of transparent plexiglas. Its 3/8 in. thickness extended back over the outside of the grid compartment. Inside the outer front compartment, this wall was 8 3/4 in. in total width—2 1/2 in. wide from either of its lateral edges to the nearest outside lateral wall of the grid compartment—and was 11 in. in total height, being 3 1/16 in. high from the bottom edge to the grid, and 4 in. high from the top edge to the top of the grid compartment. The back interior of the outer front compartment was smooth so that a mouse leaving the grid compartment could not cling.

The outer front compartment had neither a front wall nor a floor but had a ceiling and two lateral walls, all of 3/8 in. thick transparent plexiglas. These extended 23 5/8 in. forward from the interior back wall. Interiorly, the ceiling was 8 3/4 in. wide, and the lateral walls were 9 in. high.

In this ceiling were two rectangular openings, each 20 in. long and 3/4 in. wide. Exteriorly, each opening began 2 in. from the front and from the back of the ceiling and was 1 7/8 in. from the nearer lateral edge of the ceiling, and 6 7/8 in. from the other lateral edge. Atop the ceiling a 1/2 in. high plexiglas bar extended 2 in. lengthwise and 24 in. across. From this bar a 2
in. long, 1/2 in. wide plexiglas support extended down through each opening in the ceiling.

These supports held up the back part (the part nearer the grid compartment) of an "inner front compartment" inside the outer front compartment. The inner front compartment was bounded by 1/2 in. thick opaque plexiglas except on the front side, which was open. In the back wall of this compartment were two windows, each 2 1/2 in. wide x 3 in. high.

The "screen," the exterior of this wall, faced the open side of the grid compartment and was 8 1/2 in. wide x 8 7/8 in. high. The top of the screen was 1/8 in. from the interior ceiling of the outer front compartment. Each window was 1 in., 4 3/8 in., 5 in., and 1 1/2 in. respectively from the nearer lateral edge, the top edge, the farther lateral edge, and the bottom edge of the screen.

IIB-1.4. Special Features of the Apparatus

A 1/2 in. thick black opaque plexiglas wall parallel to the lateral walls partitioned the inner front compartment into two chambers each 3 1/2 in. wide. On the ceiling within each chamber was a 7 w. light bulb. Two toggle switches, each controlling a respective light, were situated on the bar above the outer front compartment.

Covering each window from the inside was a hinged colorless plexiglas door 1/8 in. thick, 2 7/8 in. wide, and 4 1/2 in. high. The doors were translucent so that they would be illuminated when the lights inside the windows were turned on. The purpose of the
partition was to prevent the light in one chamber from illuminating the door to the other chamber. The doors could be individually locked shut.

Interiorly the ceiling, the floor, and the partition of the inner front compartment were 12 1/4 in. long. However, the lateral walls of that compartment were 23 1/2 in. long interiorly. The extended portion of these walls rested on a wooden brace and thus supported the front of the inner front compartment. This brace was part of a wooden stand that held the entire jumping apparatus about 4 feet above the ground. This stand was constructed in such a way that the apparatus could not accidentally slip off or be knocked off the stand.

The rear supports for the inner front compartment could slide along the ceiling openings of the outer front compartment. The screen could thus be placed against the open side of the grid compartment or at a distance up to and exceeding 9 in. from the open side of the grid compartment. The experiment showed 9 in. to be the longest distance that any of the mice could jump.

A detachable plastic compartment 5 in. long x 3 1/2 in. wide x 8 in. high was constructed of 1/8 in. thick transparent plexiglas and was open on the back side only. This compartment could be attached in front of either chamber of the inner front compartment to enclose the chamber. This attachable compartment will be called the "chamber annex." Between its top and the top of the chamber proper was a 1/4 in. crack serving a purpose indicated later, in S. IIB-1.6.
Besides the chamber annex the apparatus had two other unattached parts. One was a 16 in. x 3 3/8 in. x 1/8 in. transparent plexiglas strip. This was wide enough to fit lengthwise into each chamber from the front and to block the width of the chamber. At the same time this strip was wide enough to cover exactly the top of the grid compartment from front to back, since this dimension of the top was 3 3/4 in. exteriorly, and since the back wall of the outer front compartment already covered 3/8 in. As will be seen, these dimensional relationships were functionally important, and the apparatus was designed with them in mind.

Another detachable part of the apparatus was a plastic box constructed of 3/8 in. thick plexiglas. Exteriorly this box was 3 3/8 in. long x 3 3/4 in. wide x 4 in. high. Only the top was open. Note that this box could fit exactly over the grid compartment, open top to open top. Projecting 4 1/2 in. laterally from the outside of this box was a 3/8 in. thick transparent plexiglas side arm, 3 3/8 in. across, having one surface in the same plane as the top of the plastic box.

The floor between the grid compartment and the windows was a 19 in. long x 15 in. wide x 1 in. high foam rubber pad 48 in. below the grid. This pad covered the bottom of a 36 in. high cardboard box open only at the top. The wooden stand itself was walled between the apparatus and the cardboard box.

IIB-1.5. The Intratrial Procedure

The intratrial procedure was carried out in such a way that
the mice were enclosed within the apparatus at all times lest the wild mice escape. Painstaking care was necessary to ensure that the compartments of the apparatus were never opened even slightly or briefly when they contained mice. Before the first trial of each daily session for a mouse, the mouse in its home cage was put in a cardboard box sufficiently high (22 in.) so that the mouse could not jump out of it. The mouse's cage was then opened, and the plastic strip was used to direct the mouse into the plastic box. When the mouse entered the plastic box, this box was thereupon covered with the plastic strip and placed upside down over the grid compartment, top to top, with only the plastic strip between the two compartments.

The lighting of the windows was then adjusted, and the appropriate window or windows were locked, according to the protocol discussed in the next chapter. The chamber annex was adjoined to the chamber with an unlocked window. A switch was then turned on to activate the time delay relay that was shown in Fig. IIB-1.3. This timer was set to deliver shock 35 sec. later.

The next step in the procedure was timed so that the mouse fell into the grid compartment 5 sec. after the timer switch was turned on. This step involved removing the plastic strip from between the plastic box and the grid compartment. As mentioned in the preceding section, the plastic box fit exactly over the grid compartment. Therefore, since the two compartments were now open to each other, the mouse with due care fell into the grid compartment.
As the mouse entered the grid compartment, the plastic strip was immediately put back over this compartment to prevent the mouse from exiting through the top. At the same time a stopwatch was started to measure latency. The heavy plastic box was left over the plastic strip to hold it in place. As the mouse left the grid compartment, during or after the 30-sec. interval preceding application of current, the stopwatch was stopped, and a record was made of latency, recorded as the stopwatch reading, and of the window to which the mouse went. If the mouse went through an unlocked window into a dark chamber, the chamber light was then turned on, since the experimenter had to see into the chamber in order to retrieve the mouse.

IIB-1.6. Retrieval of the Mice

The mouse was retrieved from the chamber by inserting the plastic strip in the crack between the ceilings of the chamber and of the chamber annex. If the mouse did not spontaneously enter the annex, the plastic strip was used to direct the mouse therein. This could easily be done because, as was mentioned in S. IIB-1.4, the plastic strip was wide enough to block the width of the chamber.

Once the mouse was in the chamber annex, the plastic strip was held over the open side of the annex, which was then detached and placed with the strip against the top and side arm of the upright plastic box. The plastic strip was then pulled across the top of the box so that the strip extended from the top edge oppo-
site the top edge with the side arm. The top of the plastic box was thus opened to the chamber annex. As the description of the apparatus would indicate, the open side of the annex covered not only the opening of the plastic box but also the side arm. It can thus be seen that the purpose of the side arm was to cover a potential opening to the outside during this step in the procedure.

If the mouse dropped into the plastic box, the plastic strip was immediately placed over the opening. If instead the mouse remained on the side arm of the box, the chamber annex was moved in the direction of the strip in order to force the mouse either into the box or onto the strip. If the mouse then dropped into the box, the strip was placed over the opening. If instead the mouse jumped onto the strip, the chamber annex was moved in the direction of the side arm to force the mouse either into the box or onto the side arm. The cycle was continued, if necessary, until the mouse jumped into the box and the strip was placed over the box. The box was then placed over the grid compartment with the strip down, and the entire procedure from that point was repeated to obtain the next trial.

If a mouse failed to enter a window upon leaving the grid compartment, the mouse fell 48 in. to the foam rubber floor below. The plastic box was then set on its side on this floor, and the plastic strip was used to direct the mouse into the plastic box. The strip was thereupon placed over the opening of the plastic box, which was then placed over the grid compartment as described above. The cycle was then repeated to obtain the next trial.
Chapter 2

THE EXPERIMENTAL DESIGN

IIB-2.1. The General Procedure

Throughout the experiment each window was illuminated, one at a time, on 50% of the trials in an irregular sequence. For each mouse, regardless of taxon or treatment group, this sequence was identical to the illumination sequence given earlier in T. IIA-1.4. Aspects of this sequence were discussed in S. IIA-1.4.

The windows were locked as described in the next two sections. When a window was locked, a mouse jumping to it would hit it and fall into the cardboard box below. A locked window was thus expected to provide the punishment essential to the experimental design.

Each experimental session consisted of ten massed trials for each mouse. The order in which the mice were run was changed randomly from each session to the next. The experimental sessions were grouped into three consecutive phases, designated respectively as pretraining, Ph. 1, and Ph. 2.

IIB-2.2. Pretraining

During pretraining, the bright window was consistently locked and the dark window was consistently unlocked to train the mice to jump to the dark window. On the first trial of each mouse's first session of pretraining, the open side of the grid compartment was 0 in. from the screen. During this session and within the remain-
ing sessions of pretraining, this distance was increased 1/4 in. per trial until the mouse made an error, i.e., failed to enter a window.

During any session of pretraining, when an error was made, the screen was moved 1/4 in. closer to the grid compartment, instead of 1/4 in. farther, on the following trial. Then, for the remainder of the session, the screen was moved away 1/4 in. per trial except after any additional errors. On the initial trial of any pretraining session besides the first, the starting distance was 1/4 in. less than it would have been had that trial been the 11th trial of the previous session. The mice could thus review what they had already learned. The above procedure evolved during pilot investigations.

Toward the beginning of pretraining, behavior was sometimes erratic. For example, besides simply going through a window or falling after hitting a locked window, mice would jump directly into the cardboard box, or would wedge between the inner and outer front compartments during early pretraining, or would go partway through a window and then turn around and run back onto the grid. Occasionally during pretraining, mice failed to leave the grid when shocked, in which case the current was turned off after 10 sec. and then turned on again after 30 additional sec.

In fixation experiments with rats, erratic behavior is common (Lal, personal communication, 1969; Liberson & Gagnon, personal communication, 1968). In the present experiment the erratic behavior of one *Microtus* was particularly troublesome. When this
mouse jumped to a window, it sat in the window and had to be pushed into the chamber in order to be retrieved.

Erratic behavior usually diminished as pretraining progressed. After any mouse had been trained to the point where the screen did not have to be moved to within 5 in. of the grid compartment for 30 consecutive trials, Ph. 1 was initiated for that mouse. Mice that had not reached criterion within 520 pretraining trials were designated as untrainable and were dropped from the experiment in Phs. 1 and 2.

IIB-2.3. Phs. 1 and 2

During Phs. 1 and 2, the screen was 5 in. from the grid compartment on every trial. The illumination sequence specified earlier in S. IIB-2.1 was begun anew at the start of each new phase. Within each taxon two mice were randomly allotted to a "No Punishment" Group, and eight mice were allotted to a "Punishment" Group. Thus, with six taxa the experiment had a 6 x 2 design with 12 subgroups.

For both the No Punishment and Punishment Groups, the bright window remained consistently locked in Ph. 1 so that the mice would continue to jump to the dark window. For the No Punishment Group, the dark window was consistently unlocked during Ph. 1 as during pretraining. For the Punishment Group, however, the dark window was locked on 50% of the trials in an irregular sequence in Ph. 1. This sequence was that shown earlier in T. IIA-1.4 whereby the dark window is locked in the IPP of the Maier paradigm. The
nature of this sequence was discussed in S. IIA-1.5. Ph. 1 consisted of 80 trials.

During Ph. 2, which consisted of 120 trials, the procedure was identical among the 12 subgroups: The left window was consistently unlocked, and the right window was consistently locked. Ph. 2 thus comprised a partial-reversal training procedure as does the usual SPP of the Maier paradigm.

IIB-2.4. The Method of Data Analysis

In the statistical analyses of the results, sums of squares were calculated by the method of Federer and Zelen (1966). Their method is applicable to data tables in which the numbers of observations form one ratio from cell to cell within any given row or column while the corresponding marginal total numbers of observations form a different ratio. In such cases their method unlike the standard method yields an exact sum of squares for any main or interactive effect though any orthogonal effects be present.

The p (probability) values reported in the next chapter are two-tailed unless stated otherwise. For p = .001, the criterion F values were obtained from Fisher and Yates (1957). The criterion F values for other p values were obtained from Snedecor and Cochran (1967).

Results were not obtained for all 60 mice, since all did not complete the experiment. The numbers of observations are given in the results tables in the next chapter. T. IIB-2.4 shows how many mice failed to complete the experiment and why they failed.
TABLE IIB-2.4
NUMBER OF MICE FAILING TO COMPLETE THE EXPERIMENT

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No punishment</td>
</tr>
<tr>
<td><strong>Mus m. C57Bl/6J</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Mus m. CF-I</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Mus m. &quot;Mo.&quot;</strong></td>
<td>1^e</td>
</tr>
<tr>
<td><strong>Microtus</strong></td>
<td>1^e</td>
</tr>
<tr>
<td><strong>Onychomys</strong></td>
<td>1^d</td>
</tr>
<tr>
<td><strong>Peromyscus</strong></td>
<td>1^e</td>
</tr>
</tbody>
</table>

Note.—A total of 19 mice failed to complete the experiment.

^a Died.

^b Became diseased.

^c Was injured.

^d Escaped.

^e Failed to pass pretraining.

^f Developed an abortive stereotype in Ph. 1.

^g Developed a right-position stereotype in Ph. 1.

^h Developed a bright-window stereotype in Ph. 1.
Chapter 3

RESULTS AND CONCLUSIONS

IIB-3.1. **Breaking and Solving**

A mouse would be considered to break when it first jumped to the bright window in Ph. 2, and the criterion of solving was that a mouse after breaking jump to the unlocked window on 29 of any 30 consecutive trials and on all the remaining trials. Among the 41 mice completing the experiment, 20 broke, and all 20 solved. A mouse's breaking score would be evaluated as the number of Ph. 2 trials that the mouse required before breaking. The mouse's solving score would be evaluated as the Ph. 2 trial following the mouse's next to last jump to a locked window. For example, if a mouse's next to last jump to a locked window were on the 51st trial of Ph. 2, its solving score would be 52. Ts. IIB-3.1a and IIB-3.1b show mean breaking and solving scores according to subgroup. Ts. IIB-3.1c and IIB-3.1d summarize the corresponding statistical analyses and indicate no significant Taxa main effect (T), Punishment main effect (P), or Taxa x Punishment interactive effect (TP) for either breaking scores or solving scores.

The last mice to solve were a *Microtus* with a solving score of 74 and a *Mus m. CF-I* with a solving score of 83. Thus, from Trial 83 through Trial 120, the last trial, of Ph. 2, the 20 mice that solved chose the unlocked window with virtually 100% frequency, whereas the remaining 21 mice continued to choose this window with 50% frequency. The final levels of choice performance thus
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Treatment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No punishment</td>
<td>Punishment</td>
<td></td>
</tr>
<tr>
<td><strong>Mus m. C57Bl/6J</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>30.0</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Mus m. CF-I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>44.0</td>
<td>48.7</td>
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</tr>
<tr>
<td>n</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Microtus</strong></td>
<td></td>
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</tr>
<tr>
<td>Y</td>
<td>21.0</td>
<td>39.3</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Onychomys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>51.0</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Peromyscus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>59.0</td>
<td>39.0</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

\(^{a}\) "Y" designates mean breaking score per mouse; "n" designates number of mice.
<table>
<thead>
<tr>
<th>Taxon a</th>
<th>Treatment</th>
<th>No punishment</th>
<th>Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mus m. C57Bl/6J</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>46.5</td>
<td>51.7</td>
<td></td>
</tr>
<tr>
<td>n</td>
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<td>3</td>
<td></td>
</tr>
<tr>
<td>Mus m. CF-I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>47.0</td>
<td>62.3</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Microtus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>74.0</td>
<td>58.7</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Onychomys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>47.0</td>
<td>63.5</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Peromyscus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>69.0</td>
<td>57.5</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

a"Y" designates mean breaking score per mouse; "n" designates number of mice.
<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa, T</td>
<td>4</td>
<td>1197</td>
<td>299</td>
<td>1.23</td>
</tr>
<tr>
<td>Punishment, P</td>
<td>1</td>
<td>187</td>
<td>187</td>
<td>.77</td>
</tr>
<tr>
<td>TP</td>
<td>4</td>
<td>1413</td>
<td>353</td>
<td>1.45</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>2426</td>
<td>243</td>
<td></td>
</tr>
</tbody>
</table>

*p > .25 for all F values shown.
### TABLE IIIB-3.1d

**ANALYSIS OF VARIANCE OF SOLVING SCORES**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa, T</td>
<td>4</td>
<td>696</td>
<td>174</td>
<td>.68</td>
</tr>
<tr>
<td>Punishment, P</td>
<td>1</td>
<td>17</td>
<td>17</td>
<td>.07</td>
</tr>
<tr>
<td>TP</td>
<td>4</td>
<td>700</td>
<td>175</td>
<td>.68</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>2566</td>
<td>257</td>
<td></td>
</tr>
</tbody>
</table>

*p > .25 for all F values shown.*
fell into a bimodal distribution for an interval exceeding a pre-
determined criterion interval of 30 trials. Therefore, since the
occurrence of such a bimodal distribution is the conventional ba-
sis for designating animals as fixated, as was indicated in Ss.
IIA-1.1 and IIA-1.7, the mice failing to solve were designated as
fixated in the present experiment.

T. IIB-3.1e shows the incidence of fixation for each sub-
group. For analysis the data of T. IIB-3.1e were transformed into
logits by the small-sample method of Snedecor and Cochran (1967,
Ss. 16.8 & 16.11). The transformed data are shown in T. IIB-3.1f,
and T. IIB-3.1g summarizes the corresponding statistical analysis.
As the earlier discussion in S. IIB-1.1 would indicate, the "pun-
ishment" (vs. "no punishment") treatment in Ph. 1 was expected to
produce a paradoxical increase in the incidence of fixation (cf.
S. IIA-3.7). T. IIB-3.1g indicates that such an effect (P) was
obtained, but that the proportion of fixated mice did not vary
among the taxa more than would be expected by chance. Also, the
Taxa x Punishment interaction was remarkable small and, as T.
IIB-3.1g would indicate, insignificant. Thus, the observed Pun-
ishment effect on fixation did not vary among the genera and
strains more than would be expected by chance.

IIB-3.2. Fixation and Behavior Prior to Ph. 2

In Ph. 1 the mice in the Punishment Group made an average of
7.09 jumps per mouse to the bright window. In fact, all the mice
in this group made at least some jumps to this window in Ph. 1,
<table>
<thead>
<tr>
<th>Taxon(^a)</th>
<th>Treatment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No punishment</td>
<td>Punishment</td>
<td></td>
</tr>
<tr>
<td><em>Mus mus. C57Bl/6J</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><em>Mus mus. CF-I</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>Mus mus. &quot;Mo.&quot;</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>Microtus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>Onychomys</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><em>Peromyscus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)"Y" designates percentage of fixated mice; "n" designates number of mice, both fixated and nonfixated.
### TABLE IIB-3.1f

INCIDENCE OF FIXATION: DATA AFTER LOGIT TRANSFORMATION

<table>
<thead>
<tr>
<th>Taxon&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Treatment</th>
<th>No punishment</th>
<th>Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mus m. C57Bl/6J</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>-1.6094</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.4117</td>
<td>1.7500</td>
<td></td>
</tr>
<tr>
<td><strong>Mus m. CF-1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>-1.6094</td>
<td>.7143</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.4117</td>
<td>1.4583</td>
<td></td>
</tr>
<tr>
<td><strong>Mus m. &quot;Mo.&quot;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>1.0986</td>
<td>11.0000</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.3750</td>
<td>.4583</td>
<td></td>
</tr>
<tr>
<td><strong>Microtus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>-1.0986</td>
<td>.7143</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.3750</td>
<td>1.4583</td>
<td></td>
</tr>
<tr>
<td><strong>Onychomyza</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>-1.0986</td>
<td>1.8000</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.3750</td>
<td>1.6071</td>
<td></td>
</tr>
<tr>
<td><strong>Peromyscus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>-1.0986</td>
<td>1.8000</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>.3750</td>
<td>1.6071</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>"Y" designates transformed proportion of fixated mice; "n" designates transformed number of mice.
### TABLE IIB-3.1g

#### ANALYSIS OF INCIDENCE OF FIXATION AFTER LOGIT TRANSFORMATION

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa, $T$</td>
<td>5</td>
<td>4.60</td>
</tr>
<tr>
<td>Punishment, $P$</td>
<td>1</td>
<td>3.32*</td>
</tr>
<tr>
<td>TP</td>
<td>5</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*p < .05 (one-tailed).*
though the mice represented in T. IIB-3.1e were all jumping consistently to the dark window before Ph. 1 ended. On the other hand, in the No Punishment Group, none of the mice ever jumped to the bright window in Ph. 1. Locking the dark window for the Punishment Group thus produced transient avoidance of the dark window in Ph. 1 and therefore (from the definitions of punishment and of avoidance) provided punishment. Furthermore, since all the mice represented in T. IIB-3.1e were consistently avoiding the bright window by the end of Ph. 1, locking the bright window may be considered to have provided punishment during this phase. Thus, since the bright window was locked consistently in Ph. 1, the Punishment Group's 7.09 jumps to that window indicates an average of 7.09 punishments at that window.

To paraphrase the results so far, the "punishment" treatment in Ph. 1 increased (a) the number of punishments at the bright window in Ph. 1, and (b) the incidence of fixation. To corroborate that the number of such punishments was more than incidentally associated with fixation, the number of punishments was compared between fixated and nonfixated mice. In order that the comparison be orthogonal to subgroup-related effects per se, it was limited to those subgroups containing both fixated and nonfixated mice. As T. IIB-3.1e indicated, 5 of the 12 subgroups had both kinds of mice, and those 5 subgroups were each in the Punishment Group and thus corresponded to five taxa, including all the taxa but Mus m. "Mo."

Since the bright window provided punishment and was consist-
ently locked in Ph. 1, the individual punishments at that window were enumerated as individual jumps to that window. In terms of the number of such punishments, the data for fixated and nonfixated mice are juxtaposed in T. IIB-3.2a. The corresponding statistical analysis is summarized in T. IIB-3.2b and comprised a Subgroups (Taxa) x Fixation (fixated vs. nonfixated mice) factorial arrangement. As such this analysis was intended to separate possible Taxon differences per se from any difference between fixated and nonfixated mice.

The significant Fixation difference indicated in T. IIB-3.2b confirms that the fixated mice made reliably more jumps to the bright window in Ph. 1 than did comparable nonfixated mice. The absence of a significant Taxa x Fixation interaction indicates that the observed difference between nonfixated and fixated mice did not vary among the genera and strains more than would be expected by chance. If additional subgroups besides the allotted five had been included in the statistical analysis, zero observations would have fallen in certain cells, e. g., the cells for nonfixated Mus m. "Mo." subjects, since no such subjects existed (cf. T. IIB-3.1e). Thus, since at least one observation is required in every cell for a factorial analysis (Federer & Zelen, 1966), the appropriate analysis would have been impossible.

The possibility was considered that the likelihood of fixation was related to the number of pretraining trials that the mice required before beginning Ph. 1. The number of such trials is shown in T. IIB-3.2c, and the results of the corresponding statis-
## TABLE IIB-3.2a

### NUMBER OF PUNITONS AT BRIGHT WINDOW IN PH. 1

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Behavioral Category</th>
<th>Not fixed</th>
<th>Fixated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mus m. C57Bl/6J</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td>8.7</td>
<td>8.0</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Mus m. CF-I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td>3.3</td>
<td>7.5</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>Microtus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td>5.0</td>
<td>9.0</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>Onychomys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td>2.5</td>
<td>8.5</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Peromyscus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td>4.0</td>
<td>9.2</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

*a"Y" designates cell mean among mice; "n" designates number of mice.*
TABLE IIb-3.2b

ANALYSIS OF VARIANCE OF NUMBER OF PUNISHMENTS AT BRIGHT WINDOW IN PH. 1

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa, T</td>
<td>4</td>
<td>31.96</td>
<td>7.99</td>
<td>1.06</td>
</tr>
<tr>
<td>Fixation, F</td>
<td>1</td>
<td>48.83</td>
<td>48.83</td>
<td>6.46*</td>
</tr>
<tr>
<td>TF</td>
<td>4</td>
<td>39.19</td>
<td>9.80</td>
<td>1.30</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>136.08</td>
<td>7.56</td>
<td></td>
</tr>
</tbody>
</table>

*p < .025. (Where p > .025, p > .25 also.)
TABLE IIB-3.2c
NUMBER OF PRETRAINING TRIALS

<table>
<thead>
<tr>
<th>Taxon\textsuperscript{a}</th>
<th>Behavioral Category</th>
<th>Not fixated</th>
<th>Fixated</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Mus} m. \textit{C57Bl/6J}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Y}</td>
<td>25.3</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>\textit{n}</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>\textit{Mus} m. \textit{CF-I}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Y}</td>
<td>28.3</td>
<td>31.5</td>
<td></td>
</tr>
<tr>
<td>\textit{n}</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>\textit{Microtus}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Y}</td>
<td>23.0</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>\textit{n}</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>\textit{Onychomys}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Y}</td>
<td>25.5</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>\textit{n}</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>\textit{Peromyscus}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Y}</td>
<td>23.0</td>
<td>35.2</td>
<td></td>
</tr>
<tr>
<td>\textit{n}</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}"Y" designates cell mean among mice; "n" designates number of mice.
tical analysis appear in T. IIB-3.2d. The data for these tables were from the same mice as were represented in the preceding tables in this section. T. IIB-3.2d suggests no evidence of any relationship between fixation and the number of pretraining trials.

IIB-3.3. Latencies for Fixated Mice

The fixated mice's latencies are shown in Fig. IIB-3.3, and T. IIB-3.3 summarizes the corresponding statistical analysis according to a Subgroups x Sessions x Windows classification of the data. The subgroups in this case were those seven that contained fixated mice as indicated by T. IIB-3.1e. The Windows factor provided comparisons between latencies for jumps to the unlocked and locked windows. Though the full three-dimensional table of means is not shown for T. IIB-3.3, Fig. IIB-3.3 shows the data in sufficient dimensionality so that the effects that are at least of borderline significance \( p < .10 \) can be visualized.

Note in Fig. IIB-3.3 that latencies were generally under 30 sec. Therefore, since shock began at 30 sec., shock avoidance rather than shock escape was the general rule. Fig. IIB-3.3 shows that latencies to the locked window were generally higher than latencies to the unlocked window in Ph. 2. This effect, the Windows main effect, was very highly significant, as shown in T. IIB-3.3, and appears to have represented learned differentiation. That is, the latency difference between the windows was negligible on Session 1 of Ph. 2 but then tended to increase from one session to the next, as Fig. IIB-3.3 shows. This increase constituted the
<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa, T</td>
<td>4</td>
<td>208.5</td>
<td>52.1</td>
<td>1.09</td>
</tr>
<tr>
<td>Fixation, F</td>
<td>1</td>
<td>41.3</td>
<td>41.3</td>
<td>.86</td>
</tr>
<tr>
<td>TF</td>
<td>4</td>
<td>250.2</td>
<td>62.6</td>
<td>1.31</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>861.1</td>
<td>47.8</td>
<td></td>
</tr>
</tbody>
</table>

*p > .25 for all F values shown.
Fig. IIB-3.3. Latencies for fixated mice in Ph. 2. In the above curves each of the 24 points (12 sessions x 2 windows) is a mean for the 21 fixated mice. The means therefore cover 21 x 24 = 504 data. Each of these 504 data was the per-trial average of the number of seconds than an individual mouse took to jump to a single window, right or left, in a particular session.
### TABLE IIB-3.3

**ANALYSIS OF VARIANCE OF LATENCIES FOR FIXATED MICE IN PH. 2**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual mice, M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgroups, G</td>
<td>6</td>
<td>3,432.123</td>
<td>572.020</td>
<td>.36</td>
</tr>
<tr>
<td>M within G</td>
<td>14</td>
<td>22,054.056</td>
<td>1,575.290</td>
<td></td>
</tr>
<tr>
<td>Within M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sessions, S</td>
<td>11</td>
<td>350.602</td>
<td>31.873</td>
<td>1.77</td>
</tr>
<tr>
<td>GS</td>
<td>66</td>
<td>1,497.776</td>
<td>22.694</td>
<td>1.26</td>
</tr>
<tr>
<td>SM within G</td>
<td>154</td>
<td>2,765.426</td>
<td>17.957</td>
<td></td>
</tr>
<tr>
<td>Windows, W</td>
<td>1</td>
<td>24,132.254</td>
<td>24,132.254</td>
<td>108.53*</td>
</tr>
<tr>
<td>GW</td>
<td>6</td>
<td>2,091.326</td>
<td>348.554</td>
<td>1.57</td>
</tr>
<tr>
<td>WM within G</td>
<td>14</td>
<td>3,112.838</td>
<td>222.346</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>(11)</td>
<td>3,634.279</td>
<td>330.389</td>
<td>28.21*</td>
</tr>
<tr>
<td>Linear</td>
<td>1</td>
<td>3,071.075</td>
<td>3,071.075</td>
<td>262.19*</td>
</tr>
<tr>
<td>Quadratic</td>
<td>1</td>
<td>274.614</td>
<td>274.614</td>
<td>23.45*</td>
</tr>
<tr>
<td>GSW</td>
<td>66</td>
<td>999.537</td>
<td>15.144</td>
<td>1.29</td>
</tr>
<tr>
<td>SWM within G</td>
<td>154</td>
<td>1,803.801</td>
<td>11.713</td>
<td></td>
</tr>
</tbody>
</table>

*p < .001. (Where p > .001, p > .05 also.)
linear component of the very highly significant Sessions x Windows interaction and was very highly significant itself, as shown in T. IIB-3.3. In fact, as T. IIB-3.3 indicates, this component provided most \((100 \times 3071.075/3634.279 = 84.5\%)\) of the Sessions x Windows sum of squares.

T. IIB-3.3 shows that the remainder of this sum of squares largely represented a very highly significant quadratic component, indicating that the increasing latency difference between the windows tended to level off significantly from one session to the next. This effect can be seen in Fig. IIB-3.3. Since the Subgroups x Windows and Subgroups x Sessions x Windows interactions were insignificant according to T. IIB-3.3, the Windows effect and the Sessions x Windows effect were not shown to have differed among the subgroups.

From one session to the next in Ph. 2, latencies tended to decrease to the left window more than they tended to increase to the right window, as shown in Fig. IIB-3.3. The net effect was thus a latency decrease from one session to the next. This effect constituted the linear component of the Sessions main effect. The Sessions main effect was of borderline significance \((.10 > p > .05)\) (cf. T. IIB-3.3).

IIB-3.4. Latencies for Fixated vs. Nonfixated Mice

Based on a Subgroups x Fixation x Sessions x Windows classification of the data, a second latency analysis was carried out to determine whether latencies or the latency effects indicated in
the preceding section differed reliably between nonfixated and fixated mice. In order to evaluate such differences orthogonally to subgroup-related effects per se, this analysis like those discussed earlier in S. IIB-3.2 had to circumvent the problem of zero observations for either nonfixated or fixated mice in any subgroup. The present analysis like those foregoing analyses was therefore limited to the five subgroups containing both fixated and nonfixated mice. In particular, the present analysis was confined to the Punishment Group, and the Subgroups factor was thus a Taxa factor. Also, since all the Mus m. "Mo." subjects were fixated, this analysis did not incorporate latencies for this strain as did the latency analysis in the preceding section.

It should be noted that latencies for nonfixated mice could not have been incorporated orthogonally into the latency analysis of the preceding section for two reasons:

1. As already indicated, zero observations were obtained for the combination of the following independent variates: (a) certain subgroups that were in the preceding latency analysis, and (b) nonfixated mice.

2. Since the nonfixated mice after solving stopped jumping to the locked window, the remaining subgroups that were in the preceding analysis gave zero observations for the combination of the following independent variates: (a) nonfixated mice, (b) the final sessions included in the preceding analysis, and (c) the locked-window variate of the preceding analysis.

In short, the latency analysis in the preceding section would
have had zero observations in various cells had the Fixation factor been included. The sources of variation in the preceding analysis thus could not have been evaluated both with their given degrees of freedom and orthogonally to fixation-related differences (cf. Federer & Zelen, 1966). With regard to the present latency analysis, the pertinent latencies were those that were comparably between nonfixated and fixated mice, and the latencies analyzed for any individual mouse were thus restricted to that session or those sessions in Ph. 2 before the mouse broke. Therefore, since the last Onychomys to break did so during Session 3, zero applicable observations were obtained for the combination of the following independent variates: (a) Onychomys, (b) nonfixated mice, (c) sessions beyond the second, and (d) the locked-window variate. Hence, one of these variates had to be excluded from the analysis, which was accordingly confined to the first two sessions of Ph. 2.

In the preceding section it was noted that the Windows effect and the Sessions x Windows effect were very highly significant for fixated mice. If these effects varied sufficiently between fixated and nonfixated mice, the Fixation x Windows and Fixation x Sessions x Windows interactions in the second latency analysis would have been significant. Such was not the case, however: This analysis is summarized in T. IIB-3.4 and indicates no significant differences. The Windows effect and the Sessions x Windows effect on latencies therefore did not vary reliably from fixated to nonfixated mice, nor did mean latencies as indicated by the absence
TABLE IIB-3.4
ANALYSIS OF VARIANCE OF LATENCIES FOR FIXATED VS. NONFIXATED MICE IN PH. 2

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual mice, M</td>
<td>(26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixation, F</td>
<td>1</td>
<td>182.082</td>
<td>182.082</td>
<td>.73</td>
</tr>
<tr>
<td>TF</td>
<td>4</td>
<td>1046.717</td>
<td>261.679</td>
<td>1.04</td>
</tr>
<tr>
<td>M within T &amp; F</td>
<td>17</td>
<td>4266.237</td>
<td>250.955</td>
<td></td>
</tr>
<tr>
<td>Within M</td>
<td>(79)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS</td>
<td>1</td>
<td>5.234</td>
<td>5.234</td>
<td>.67</td>
</tr>
<tr>
<td>TFS</td>
<td>4</td>
<td>45.570</td>
<td>11.392</td>
<td>1.46</td>
</tr>
<tr>
<td>FSM within T &amp; F</td>
<td>16</td>
<td>125.092</td>
<td>7.818</td>
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<tr>
<td>FW</td>
<td>1</td>
<td>6.024</td>
<td>6.024</td>
<td>.49</td>
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<tr>
<td>TFW</td>
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<td>28.190</td>
<td>7.048</td>
<td>.57</td>
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<tr>
<td>FWM within T &amp; F</td>
<td>17</td>
<td>210.260</td>
<td>12.368</td>
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</tr>
<tr>
<td>FSW</td>
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<td>5.038</td>
<td>5.038</td>
<td>.97</td>
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<tr>
<td>FSMW within T &amp; F</td>
<td>16</td>
<td>82.754</td>
<td>5.172</td>
<td></td>
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</table>

Note.—T = Taxa; S = Sessions; W = Windows.
*p > .25 for all F values shown.
of a significant Fixation main effect.

IIB-3.5. **Conclusions**

This experiment demonstrated that locking the window currently correct (dark) in Ph. 1 provided punishment (S. IIB-3.2), and that this punishment resulted, paradoxically, in an increased likelihood that jumping to this window would later persist as fixation (S. IIB-3.1). These findings can be interpreted as follows in conjunction with the additional results that were obtained. Since the correct window in Ph. 1 was frequently locked for the Punishment Group, the mice in this group sometimes avoided this window by jumping to the incorrect (bright) window during this phase (S. IIB-3.2). On the other hand, since the correct window in Ph. 1 was consistently unlocked for the No Punishment Group, the mice in this group never jumped to the incorrect window during this phase (S. IIB-3.2). In Ph. 1, therefore, the mice in the Punishment Group were, in effect, trained to avoid the then-incorrect window, which was shown to provide punishment, whereas the mice in the No Punishment Group received no such training in Ph. 1.

To paraphrase in more rigorous language, the incorrect window in Ph. 1 provided more effective punishment for the Punishment Group than for the No Punishment Group, by the number-of-punishments criterion (cf. S. IIB-1.1). Hence, if fixation be viewed as trained avoidance of that window, as has been maintained (e.g., cf. S. IIA-2.5), the incidence of fixation would be ex-
pected to have been greater for the Punishment Group than for the No Punishment Group, as was confirmed (S. IIB-3.1). In corroboration that fixation represents trained avoidance by the number-of-punishments criterion, fixated mice averaged more punishments at the incorrect window in Ph. 1 than did nonfixated mice that were comparable as to taxon and treatment group (S. IIB-3.2).

Latency differentiation by fixated mice was observed (S. IIB-3.3) and rules out the interpretation that the observed fixations represented insensitivity to the ongoing punishment contingency on the fixated choice in Ph. 2 (cf. S. IIB-2.1). In fact, within the Punishment Group, latencies and latency differentiation were virtually the same for fixated mice as for nonfixated mice in Ph. 2 (S. IIB-3.4). The fixations observed in this experiment thus do not appear to have represented even a relative insensitivity within this group. No significant differences among the taxa were obtained.

The foregoing interpretation of the present results corresponds essentially to the instrumental model that was discussed in S. IIA-3.7. Qualifications to this model were noted in Ch. 4, Part IIA, and might apply to the present findings. Specifically, locking the window currently correct in Ph. 1 might have vitiated the effectiveness of punishment for the Punishment Group in Ph. 2 and might thereby have contributed to the relatively greater incidence of fixation for this group. This interpretation, like the foregoing interpretation, is consistent with the premise that fixation represents trained avoidance—i.e., that the occurrence of
fixation reflects the balance between previous punishment of the abandoned choice and ongoing punishment of the choice that is practiced in Ph. 2 (cf. S. IIA-2.5).

In short, the present results support the proposal that fixation represents trained avoidance of the window that was incorrect in Ph. 1. This proposal clarifies the permanent nature of fixation. In Ph. 2 of the usual fixation experiment, fixated animals as such do not jump to the window that was incorrect or nonpreferred in Ph. 1. Hence, their avoidance of that window cannot undergo extinction, and their behavior is caught in a "vicious circle." Fixation can thus be viewed as a self-perpetuating suspension of extinction training. Accordingly, several experiments have shown that fixations do not materialize or are readily broken (on free-choice trials) when extinction training is enforced by guiding rats to the unlocked window in Ph. 2 (see S. IIA-3.2). That this effect of guidance largely represents extinction rather than learning-by-doing is indicated by a finding (Maier & Klee, 1945), discussed earlier in S. IIA-3.2, that the guidance procedure in itself does not greatly influence rats' free choices but primarily serves to permit their free choices to develop in configuration with the ongoing punishment contingencies.

In conclusion, it may seem paradoxical that punishing a response should perpetuate performance of that response as was shown, but it has been demonstrated that the paradox dissolves when the circumstances of punishment and performance are considered analytically. Yet punishment effects such as that shown do
seem foreign to everyday notions about punishment and perhaps for this reason have received only scant acknowledgement in the general behavioral literature (cf. Yates, 1962, Ch. 1). Hopefully, through the present theoretical and experimental analysis of fixation, such facilitatory effects of punishment have become more understandable in relation to the familiar operational concepts of training.


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APPROVAL SHEET

The dissertation submitted by David S. Stark has been read and approved by three members of the faculty of the Graduate School.

The final copies have been examined by the director of the dissertation, and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval with reference to content, form, and mechanical accuracy.

The dissertation is, therefore, accepted in partial fulfillment of the requirements for the degree of Master of Sciences.

May 9, 1973

Date

Charles J. Scudder
Signature of Advisor