BLOCKING THE ACQUISITION OF STIMULUS CONTROL

BLOCKING THE ACQUISITION OF STIMULUS CONTROL IN OPERANT DISCRIMINATION LEARNING

by

Walter vom Saal

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AUTHOR: Walter vom Saal, B.A. (Columbia University)

SUPERVISOR: Professor H. M. Jenkins

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SCOPE AND CONTENTS:

At least five different uses of the term "attention" can be detected in the literature on animal discrimination learning. One of these predicts "blocking": decreased learning about one of two covarying cues, resulting from prior training to discriminate on the basis of the other cue. In Experiment 1, four groups of 6 pigeons received different sorts of training in Phase 1; in Phase 2 all groups received go/no-go discrimination training in which positive trials (tone; pale red key) and negative trials (noise, pale green key) differed on both an auditory and a visual dimension. A group that received Phase 1 training to discriminate on the basis of the visual cue alone showed less stimulus control by tone-noise on a test given after all training than did a control group that received no Phase 1 training. It is concluded that acquisition of control by the auditory cue in Phase 2 was blocked by prior training to discriminate on the basis of the visual cue. Results for the two remaining groups and a detailed analysis of the test data rule out certain alternative explanations of the reduced auditory control, including the possibilities that it resulted from (a) the occurrence of any Phase 1 training, (b) partial reinforcement received during Phase 1 discrimination training, (c) training with an auditory value present but not predicting reinforcement during Phase 1, or (d) an interaction on the test for stimulus control.

Three subsidiary experiments involving a total of 20 pigeons show that blocking the acquisition of visual control by prior training on an auditory discrimination may also occur, but do not conclusively demonstrate it. In a concluding discussion it is argued that, although the results of the first experiment are evidence for "blocking" as defined here, the results do not require a two-stage model of learning for their explanation.

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CHAPTER 1

THE CONCEPT OF ATTENTION IN ANIMAL LEARNING

The term "attention" has had an uneven history in psychology. William James, considering it one of the most evident phenomena of our experience, devoted a champter to it in his famous Principles of Psychology. In defining it, he made reference to experiences which everyone shares:

> "Every one knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others....." (1890, p. 402-403).

As experimental psychology developed in the twentieth century, the term attention became less and less popular. One reason for this decline was a shifting approach to psychology which increasingly emphasized the need for dealing with observables available to everyone. Psychologists became uncomfortable with definitions of the sort quoted above because they dealt with subjective phenomena that could not be observed or manipulated directly. This reluctance to deal with subjective phenomena even led to a gradual change in the definition of psychology, from "the Science of Mental Life" (James, 1890) to "the science of behavior and experience" (cf. Woodworth, 1921) to "the science of behavior" (Keller

& Schoenfeld, 1950).

As the goal of psychology shifted from understanding experience to understanding behavior, the term attention was used less and less. It was thought that the laws governing the behavior of men and animals could be stated without using the concept of attention. In the early twentieth century, a reflex model of behavior was adopted according to which behavior was seen as largely, almost exclusively, determined by stimuli currently present in the environment. It was thought that all learning could be reduced to the acquisition of "stimulus-response bonds", and that a knowledge of the state of these S-R bonds, and of the stimuli occurring in the environment, would enable prediction of the behavior that would occur. The concept of attention, with its implication that the animal actively selects its stimulus input, did not fit readily with the reflex model. Later, the reflex model was dropped in favor of Thorndike's law of effect. The consequences of responding were emphasized, and in some formulations the stimulus was considered to "set the occasion for" the response rather than to produce it directly as a prod. However, the view of stimuli leading directly to responses was retained. The basic theories of learning proposed in the 1930's still implied a view which considered the animal more a passive recipient of external stimulation than an active selector of his sensory input. These theories still had no place for active selection of stimuli on the part of the animal*, and still found little use for the concept of attention.

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* However, this did not mean that all available stimuli must enter equally into every association. For instance, some stimuli might be more distinctive than others, and these might become more strongly connected to the response than less distinctive stimuli also present. Since distinctiveness is a static variable, however, and was considered to remain unchanged through the life of the animal, it is quite different from "active selection" of the stimuli entering an association. The notion of distinctiveness is discussed further on p. 9.

Those basic theories of learning, which will be referred to here as "traditional" theories, have been successful in explaining a wide variety of experimental findings. Some psychologists have felt, however, that any theory that assumes all stimuli acting at the time of response become associated with that response must be incorrect. As early as 1942, Lashley presented "evidence ... inconsistent with the proposition that all stimuli which affect the sense organs during a reaction are associated with that reaction", and concluded that "only those stimuli or aspects of a stimulus to which the animal is set to react during training will elicit the discriminative reaction after training" (1942, p. 260). The experiments which led Lashley to this conclusion involved training rats to discriminate between two stimuli which could be distinguished on the basis of either of two variables (e.g. "size" or "shape" of a visual stimulus). Lashley concluded that animals who could use either of the two stimulus variables to perform the correct response often used only one of those variables. This finding seemed inconsistent with traditional theories, and suggested that "attention" might be involved in determining to which stimulus variable the rats would respond.

Psychologists have cited several lines of evidence suggesting that traditional theories of learning do not adequately account for the ways animals behave, that all stimuli acting at the time of response do <u>not</u> necessarily become associated with that response. And in general, it is evidence supporting this view that has led to the reintroduction of the term attention. It is important to notice that the evidence now leading psychologists to speak of attention is based not on phenomenological experience, but on observed regularities in behavior. An empirical and theoretical understanding of these regularities is of primary importance if we wish to achieve the goal of a more complete understanding of behavior.

The term attention, then, implies certain regularities and relationships in our data, and it is these relationships that are important rather than the term itself. The term is often introduced, however, without making clear to what relationships the term is meant to apply. Perhaps because of its wide use in everyday language, it is often left undefined, and it sometimes seems to have different implications in different situations. Not all of these implications go beyond the reach of traditional theories of learning. It may be that the observations leading us to use the term attention will turn out to require modification and extension of traditional theories, but before any decision can be reached on this necessity, the different implications of the term will have to be made precise.

The remainder of this chapter is an attempt to describe at least some of the relationships that the term attention implies. To do this, five different "meanings" of the term attention, as it might be applied to animal discrimination learning, will be described. Although it is unlikely that a rigorous division of the implications of the term into these five classes could be defended, the division will serve as a reminder that, unless carefully defined, the term attention cannot be considered to refer unambiguously to a single set of relationships. The attempt here is not to conclude that attention should be defined in terms of one of these relationships rather than another, but rather to make a clear distinction between different sets of relationships which have sometimes been confused. The distinctions made will prove valuable in discussing the experiments that follow.

Meaning 1: attention as stimulus control

Consider a situation in which a pigeon pecks a small disk when it is red, but does not peck the disk when it is green. Assume that the only variable manipulated by the experimenter in this situation is the color of the disk, and that the pigeon's rate of pecking is observed to be correlated with changes in this variable. Observations such as this have been described by using the term "stimulus control": it would be said of the above situation that the color of the disk controlled the pigeon's pecking response. More generally, a stimulus variable such as color is said to control a response if changes in that variable cause correlated changes in the rate of response (Terrace, 1966). If, on the other hand, changes in the color of the disk produced no changes in the rate of pecking, we would say that the color of the disk did not control pecking*.

Observations such as these have been considered by some to be sufficient reason to use the term attention. The observation that the pigeon's response did or did not covary with changes in the color of the disk would be used to conclude that the pigeon attended, or did not attend, to disk color. Skinner argued, for example, that "attention is a controlling relation - the relation between a response and a discriminative stimulus. When someone is paying attention, he is under special control of a stimulus" (1953, p. 123). Skinner here applies the term attention to the sort of behavioral relationship which has led others to speak of stimulus control.

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* Alternative terminologies, used interchangeably in this paper, might speak of responding as controlled by "the color dimension" or "the visual cue". Each of these phrases is simply a shorthand way of referring to the more specific relations described; no additional implications are intended.

There does seem to be some basis for defining attention in this way. In many studies measuring stimulus control, it is found that a certain response is controlled by one stimulus variable (e.g. color of a light) but not by another stimulus variable (e.g. the intensity of a background noise). This is precisely the sort of situation which might lead us to speak of attention. In a paper on "selective attention", for example, Egeth states that "the present paper is concerned with the process of attention. In particular, it is concerned with the description of those mechanisms which enable organisms to respond selectively to important features of their environments while ignoring features which are of little or no importance" (Egeth, 1967, p. 41). One could argue that selective attention is selective stimulus control, and that the mechanisms responsible for attention are just those found to be responsible for stimulus control. One such "mechanism" might involve differential reinforcement, which is known to increase stimulus control (Terrace, 1966). When an animal is reinforced for a particular response in the presence of one stimulus value and is nonreinforced in the presence of another stimulus value, the stimulus variable involved gains increased control over the response. Thus differential reinforcement might form the basis of a "mechanism" enabling animals to respond selectively to features of their environments that are "important" in the sense that they predict when reinforcement will occur. Features of the environment that do not predict reinforcement and do not acquire stimulus control could be considered to be "ignored". The term attention would apply to any situation in which some stimuli controlled responding but others did not.

If the terms "attention" and "stimulus control" are synonymous, is there any reason to choose between them? There seem to be two reasons to prefer the term stimulus control as a descriptive label for the sorts of relationship described here. First, the stimulus control has been more precisely defined (Terrace, 1966) and generates more precise usage. Second, the term attention has other implications, and it seems best to reserve it for situations in which these other implications are made explicit. In addition, it should be pointed out that the observation that a given stimulus does or does not control responding is the sort of observation directly dealt with in the traditional theories of learning mentioned above. If the term attention is to be used only where these theories are inadequate then the term would not apply indiscriminately to every situation in which stimulus control is observed.

Meaning 2: attention as the possibility of stimulus control

The second meaning can be dealt with quickly, since it has much in common with meaning 1. It modifies meaning 1 slightly, however, in order to remove a source of difficulty not mentioned above. That difficulty is shown clearly in an experiment by Hearst (1962), who trained monkeys to perform two responses concurrently. The monkeys pressed a lever protruding from the wall and pulled a chain hanging from the ceiling. After the responses had been well trained, Hearst changed the intensity of the light illuminating the monkeys' working chamber. He found that the monkeys' rate of chain pulling depended on the light intensity, but the rate of lever pressing did not. According to one response measure, the monkeys were attending to the light; according to another they were not. More generally, it will frequently be the case that one response measure shows control by a stimulus, while other concurrently occurring responses do not.

In order to get around this problem, attention might be defined as the possibility of stimulus control. According to this definition there would be an asymmetric relation between attention and stimulus control: the occurrence of stimulus control would imply the existence of attention, but lack of stimulus control would not imply the absence of attention.

This meaning of attention is not much more satisfactory than meaning 1. To say that attention is the possibility of stimulus control is of little value if no independent criterion of attention is given, since one might conclude that an animal was attending but it would be difficult to conclude that he was not attending. And again, it seems likely that the term attention implies other relationships, and should be reserved for situations in which these relationships are demonstrated.

Meaning 3: attention as manipulable stimulus control

Let us consider an experiment by Reynolds (1961) which has been widely cited as demonstrating attention. In the experiment two pigeons were taught to discriminate between a white triangle on a red background and a white circle on a green background. The pigeons could learn to respond correctly on the basis of color, shape, or both. A subsequent test indicated that one pigeon was controlled by color but not by shape, the other by shape but not by color. The concept of attention was used to explain the unpredictable manner in which different dimensions of the stimuli came to control responding.

Although some authors have held that this experiment involved attention, others have pointed to an alternative explanation which should be ruled out first. It is known that there are species differences in the sensitivity of different animals to different sorts of stimuli. Visual stimuli are thought to be especially distinctive for pigeons, whereas auditory stimuli are more distinctive for rats, and so on.* It is likely that such built-in differences exist within species as well as between species, and we might wonder whether the differences observed in Reynolds' experiment were due to such effects. If in Reynolds' situation we could manipulate which of the cues came to control the response, we could rule out the possibility that built-in differences were at work, and would be more likely to speak of attention. More generally, we might speak of attention in any situation in which manipulation of controlling relations was possible. Such manipulation might occur within individual subjects, or between different subjects assumed to start out equal. The word "manipulation" would have to be carefully defined so as to exclude the sort of manipulation known to establish stimulus control - discrimination training, for example. One way to do this might be to require manipulation that is quite rapid and perhaps reversible - we might wish to speak of "switchable" stimulus control.

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* As used here, the <u>distinctiveness</u> of a particular pair of stimuli refers to the ease with which they may be discriminated in some standard situation. To say that visual stimuli are more distinctive for pigeons than for some other organism is to say this: if two pairs of stimuli were chosen, one visual and one non-visual (e.g. auditory), which were equated in terms of discriminability for some other organism (e.g. a human), then the pigeon could learn to discriminate between the two visual stimuli more readily than he could learn to discriminate between the two non-visual stimuli. Certain relationships concerning distinctiveness are likely to cut across species. For example, the stimulus pair red-green is likely to be more distinctive than the pair red-orange for a variety of organisms. It should be noted that, as used here, "distinctiveness" is a term applied to <u>pairs</u> of stimuli, not to individual stimuli.

Perhaps the best way to demonstrate such rapid manipulation would be to bring the whole controlling relationship itself under stimulus control. For example, Cross (1965) presented humans with auditory stimuli which differed in two dimensions, fundamental frequency (A) and modulation rate (B). During training 3 stimuli were presented which differed along these dimensions; these stimuli may be symbolized A_1B_1, A_1B_2, and A_2B_1. Subjects could respond by pressing a response key to the right or to the left. The correct response to each of the auditory stimuli depended on an additional visual stimulus (whether an amber or a blue light was lit), as indicated in the following table.

AUDITORY STIMULUS	CORRECT RESPONSE	
	amber light on	blue light on
A_1B_1	press left	press left
A_1B_2	press left	press right
A_2B_1	press right	press left

During training, the visual stimulus indicated what dimension of the auditory stimulus could be used to perform the correct response. A test for stimulus control given after training showed that dimension A controlled responding when the amber light was on, dimension B when the blue light was on. This is an example of manipulable stimulus control, since the experimenter could manipulate auditory control over the response by varying the visual stimulus.

The notion of manipulable stimulus control, then, might be considered to apply to situations where changes in one stimulus affect the controlling relation between a second stimulus and a response. In an early discussion of complex behavior in lower organisms, Jennings (1906) implied a definition of attention based on such a relationship:

> Is not what we call <u>attention</u> in higher organisms, when considered objectively, the same phenomenon that we have called the interference of one stimulus with the reaction to another? At the basis of attention lies objectively the phenomenon that the organism may react to only one stimulus even though other stimuli are present which would, if acting alone, likewise produce a response. The organism is then said to attend to the particular stimulus to which it responds. This fundamental phenomenon is clearly present in unicellular organisms. Stentor and Paramecium when reacting to contact with a solid "pay no attention" to a degree of heat or a chemical or an electric current that would produce an immediate reaction in a free individual (1906, p. 330).

Jennings refers to the following situation:

$$\begin{aligned} S_1 &\longrightarrow R_1 \\ S_2 &\longrightarrow R_2 \\ S_1 + S_2 &\longrightarrow R_2 \text{ only.} \end{aligned}$$

When S_2 is not present, S_1 produces R_1. That is, the stimulus variable presence-absence of S_1 controls R_1. When S_2 is present, however, S_1 does not produce R_1: the stimulus variable presence-absence of S_1 does not control R_1. In other words, whether or not presence-absence of S_1 controls R_1 depends on S_2. S_2 is a stimulus which affects the controlling relation between a second stimulus and a response. When viewed in this way, Jennings' definition seems to fall under what we have called manipulable stimulus control.

The situation Jennings describes is particularly interesting in that it suggests ways in which we might like to limit the notion of manipulable stimulus control. For instance, some kind of response interference might be at work in the situation he described: the response to S_1 may be prevented not by S_2, but by the strongly occurring R_2. Even if this were the case, we would still speak of reduced stimulus control by S_1, since stimulus control is defined in terms of an observed relationship between stimuli and responses. However, we might want to rule out cases in which reduced stimulus control resulted from "response interference" (a term which would have to be more carefully defined). Another possibility concerning Jennings' situation is that the relationships he describes are better understood by simply speaking of the responses produced by different stimulus combinations - we might want to speak of "complex stimulus control".

Whether or not the possibility of "response interference" or "complex stimulus control" should be ruled out before speaking of "manipulation of stimulus control" will not be discussed here; the issues are complex. It may be that the class of situations covered by the phrase "manipulation of stimulus control" is too broad to be useful, and should be either subdivided or rejected in favor of other distinctions. However, as the quote from Jennings shows, in at least some cases the term attention is used to apply to all situations in which a change in one stimulus affects the controlling relation between a second stimulus and a response.

Meaning 4: attention as a trading relation

Another implication of the term attention is that there is only a limited amount of it available. Recall that in the experiment by Reynolds described above, each of the pigeons was controlled by only one of the stimuli. We might suspect that in Reynolds' situation increased control by one stimulus implied decreased control by the other. The fourth meaning of attention reserves it for situations where increased control by one stimulus dimension is found to be accompanied by decreased control by a second stimulus dimension. Such a relation will be termed a trading relation.

The term attention often implies this sort of trading relation. This implication may be seen in James' definition of attention, quoted on p. 1 above. More recently, data suggesting that perception involves "central mechanisms of limited capacity" (Broadbent, 1965, p. 459) and that there are "limits on our capacity for processing information" (Miller, 1956, p. 81) imply the existence of such a trading relation. Another notion which implies a trading relation of the sort described here is the "pie hypothesis" described by Switalski, Lyons, & Thomas (1966), according to which there is a limited amount of stimulus control available to be divided up among particular stimuli.

The implication of a trading relation (meaning 4) seems independent of the implication of manipulability (meaning 3). It is possible to conceive of "switching on" large classes of stimulus control without simultaneously "switching off" other classes (an animal might become controlled by tonal frequency without losing previous control by light intensity), and it is possible to conceive of mechanisms that would imply a trading relation without at the same time making stimulus control "switchable" (even if stimulus control could be only gradually increased, e.g. by discrimination training, this might produce a gradual decrease in stimulus control by another dimension).

Assuming that a trading relation existed, we might divide the manipulations affecting stimulus control into two classes. The first class would not depend on the existence of a trading relation. It would include those manipulations that might be expected to affect stimulus control directly – for instance, through the formation of S-R bonds. Such manipulations might include discrimination training, in which the stimuli are correlated with reinforcement, and what might be called "specific irrelevance training", in which stimuli vary in a manner uncorrelated with reinforcement. Discrimination training would be expected to increase stimulus control by forming S-R bonds of different strengths to different stimuli; specific irrelevance training would reduce stimulus control, perhaps by forming S-R bonds of equal strength. Although specific irrelevance training is not always described as basic when stimulus control is discussed, Hull has described a mechanism by which such training could lead to the "practical neutralization" of a stimulus-response bond (1952, p. 64-68), and a process of "adaptation", in which "responses become independent of the irrelevant cues" is basic to Restle's (1955) theory.

The first class of manipulations affecting stimulus control, then, includes those that might be expected to affect stimulus control directly. That class does not require the existence of a trading relation. If a trading relation existed, however, this would add a second class of manipulations affecting stimulus control. This second class of manipulations would include those that affect stimulus control indirectly, through the trading relations involved. For example, if discrimination training on S_1, which we would expect to increase control by S_1, were found in addition to decrease control by S_2, we would have evidence for the sort of trading relation described above.

The definition of "trading relation" offered above implied that the term referred to a relation between the stimulus control observed over a single response by two different stimulus dimensions on some kind of test for stimulus control. The term trading relation need not be restricted in this way, however. There are at least two ways in which it can be expanded to refer to a wider set of relationships. First, it might also be used to refer to situations where more than one response is considered. For example, it might be found that increased stimulus control by one stimulus dimension over one response was accompanied by decreased stimulus control by another stimulus dimension over a second response.

Second, the trading relation need not occur on a test for stimulus control, but might occur during learning. It is known that stimulus control is acquired during discrimination learning in which the animal learns to make a response in the presence of one stimulus but not to respond in the presence of another. Since this sort of learning may be considered the acquisition of stimulus control*, it seems possible that under certain conditions a trading relation could occur during such learning. For example, an animal who was already controlled by one stimulus dimension might acquire less control by an added dimension than an animal without prior control. That is, prior learning might reduce learning about an added stimulus dimension. The remaining chapters of this thesis deal in more detail with the possibility that such a trading

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* See p. 25-26 below.

relation may occur during learning.

Meaning 5: attention as a mediating response

It is possible to conceive of learning as a two-stage process in which the first stage involves learning what stimuli to attend to, and the second stage involves learning to attach responses to those stimuli. The fifth meaning of attention identifies it with the first stage in such a two-stage process. When used in this way, the exact implications of the term attention depend on the specific two-stage model of learning that is proposed, and the value of the term depends on the validity of the model. The term is reserved for situations in which the model is applicable.

Although specific two-stage models of this sort have been proposed, it is often the case that such a model is implied but not described in detail. Terms such as observing response, orienting response, and receptor orienting response imply a two-stage model of learning in which the first stage is the acquisition of some at least potentially observable movement that makes the relevant stimuli available. Terms such as attentional response, stimulus classification, switching in the relevant analyzer, stimulus coding, gating mechanism, and stimulus filtering imply a model in which the first stage refers to some internal mechanism which cannot be directly observed. The distinction between an external and an internal first-stage mechanism has seemed important, since if the first stage were external it might be manipulated and observed directly. However, since in most situations this is not attempted, what is much more important than whether the first stage is internal or external are the predicted functional relations between the observed stimuli and responses. As Kendler and Kendler have pointed out, "the 'validity' of the mediational mechanism does not depend on (its) being coordinated with observable events, but depends instead on (its) being utilized in a successful explanatory system" (1962, p. 7).

The functional relations between observed stimuli and responses may not depend on whether the first stage is considered to be an external or an internal response. In fact, when a term such as "stimulus filtering" is used but no model is described in detail, the implication is often this: you are justified in speaking of central attention if you can identify something in performance parallel to the effects expected if there <u>were</u> external observing responses. When a model is formulated this vaguely, it is difficult to make precise predictions from it. Lawrence (1963) has pointed out the importance of whether or not the mediating response is controlled by the same stimuli as the second stage response*, and different predictions also result from different assumptions regarding the relative rates of formation of mediating and second-stage responses (Mackintosh, 1965b, p. 135), the relative rates of extinction of mediating and second-stage responses (Mackintosh, 1965b, p. 145), and the forms of feedback which govern the formation of mediating responses (compare Sutherland & Holgate, 1966, p. 206, and Lovejoy, 1966).

Even when vaguely formulated, however, a two-stage model does have several general implications. It suggests certain independent

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[*] The question of the relation between stimuli controlling the mediating and second-stage responses has led to apparent inconsistencies in the "analyzer" theory discussed by Sutherland and Mackintosh: cf. Mackintosh, 1965a, p. 299; Sutherland & Holgate, 1966, p. 205.

variables (a warning signal, or instructions to human subjects, might improve performance) and certain dependent variables (orienting responses might be observed). If the attention response is under the control of stimuli different from those controlling the second-stage response, a variety of broad transfer phenomena not restricted to the particular second-stage response might be expected.

In addition, a two-stage model might predict any or all of the relationships discussed above under the first four meanings. It is important, however, that a two-stage model _need_ _not_ _necessarily_ predict those relationships. One can conceive of two-stage models in which attention is established slowly and is not "switchable" - a model sufficient to account for the overlearning reversal effect could be of this sort. And a two-stage model need not necessarily imply a trading relation of the sort described under meaning 4. Whether or not a trading relation were implied might depend, for instance, on whether the stimuli were from the same or different modalities, or on their physical location in the environment.

Even if a particular two-stage model did predict trading relations or "switchability", these predictions might be based on aspects of the model that could be considered independent from other aspects. For example, Sutherland has developed a two-stage model which is sometimes described as including a postulate about a trading relation (Sutherland, 1964a; Sutherland & Mackintosh, 1964), and sometimes not (Sutherland, 1964b). When such a postulate is included, it is stated as a separate rule (Sutherland, 1964a). If the trading relations predicted by the model were found to exist, this need not necessarily support other aspects of the model. Alternatively, if the predicted trading relations failed to occur, not all aspects of the model would have to be rejected.

Just as a two-stage model need not necessarily predict the relationships described under meanings 3 and 4, these relationships do not necessarily require a two-stage model for their explanation. In many circumstances the occurrence of "switchable" stimulus control might be considered control by complex stimuli (or "conditional" stimulus control) and not evidence of attention at all. Similarly, trading relations might occur that could be explained without recourse to a two-stage model. Alternative explanations of one sort of trading relation will be discussed in Chapter 6 below.

It was pointed out above that the use of the term attention has depended in part on the extent to which traditional theories of learning fail to account for experimental observations. Of the five meanings which have been presented, the fifth comes closest to making that failure of traditional theories an explicit requirement. The first two meanings of attention relate it to the observation that a given stimulus does or does not control responding; this is the sort of observation directly dealt with in traditional theories. Similarly, the relationships described under meanings 3 and 4 can be explained in terms of traditional formulations in at least some situations. In contrast, meaning 5 requires a situation in which traditional theories are inadequate and a two-stage theory is required. It should be noted, however, that not every finding outside the reach of traditional theory will be susceptible to explanation by a two-stage theory, and not every finding that can be explained by a two-stage theory will require a two-stage theory whose first stage is the acquisition of an "attention response". A two-stage theory whose first stage is quite in line with traditional formulations has been described by Goss (1955). That theory, which can explain observations sometimes taken as evidence for attention, will be discussed in Chapter 6.

Conclusions

This chapter has attempted to show that the term attention implies several different relationships in the data, and that these relationships are logically independent. It is not suggested that any one of these relationships be adopted in a definition of attention and the others rejected. What is more important is to attempt to explain these relationships by placing them in a larger systematic context. As was pointed out in introducing this chapter, the term attention seems to be used in situations where traditional theories of learning seem incapable of accounting for the behavior observed. Our goal might be to modify and extend the traditional principles so that they *can* explain the behavior occurring in these situations.

One approach toward this goal has been to see what body of evidence can be gathered for the concept of attention. If this is done, it must be borne in mind that the term attention has too many different implications to be used without careful definition. There may be a great many experiments supporting the use of the term attention, but it is questionable whether the attention they support has the same meaning in each case. A demonstration of "attention" or "attention-like-processes" first requires making clear what meaning is assigned to the term attention, what regularities and relationships in the data will be accepted as evidence for attention. It has sometimes been the case that findings supporting different implications of the term attention are considered together as supporting a unitary concept. For example, in a review of experiments supporting the notion of "selective attention in animal discrimination learning", Mackintosh (1965b) reviews experiments on "single stimulus pretraining" which attempt to determine whether discrimination training is necessary to establish stimulus control. These experiments seem most relevant to "attention" when attention is defined as in meanings 1 and 2. However, Mackintosh indicates in other parts of his paper that for him the term attention has a meaning closer to meaning 5.

A second approach to the goal of better understanding the sorts of relationships described above might be this: take a phenomenon that has figured largely in discussions of attention, and examine the extent to which it involves processes that are beyond the reach of traditional formulations. This is the approach taken here. The experiments reported in this thesis deal with one of the relationships described above, the trading relation. The possible factors underlying this relation in one situation are considered in some detail. After the results of the experiments have been described, their implications for a two-stage model of learning will be briefly discussed.

CHAPTER 2

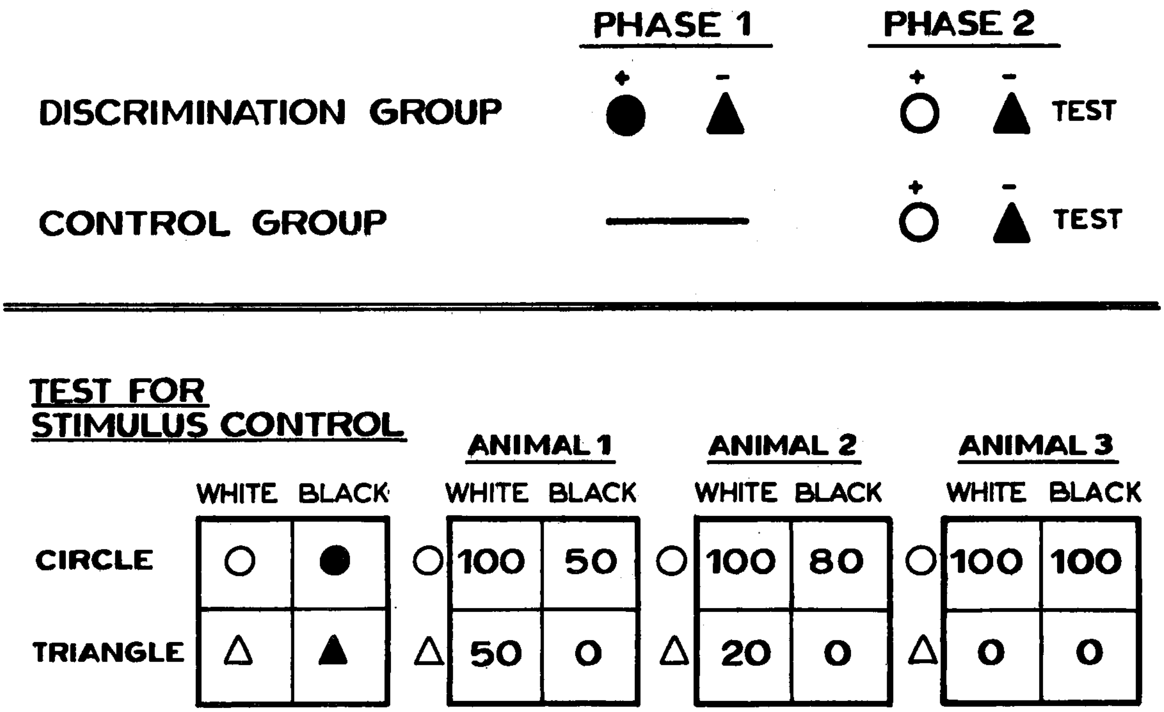
THE BLOCKING DESIGN

The experiments reported in this thesis are based on variations of a single basic design, which will be called here the "blocking" design. In this chapter that design is introduced and discussed. The possibility that the acquisition of stimulus control may be "blocked" is considered, and predicted test results which would follow from blocking are described. Alternative explanations for those test results, which would have to be ruled out before one could conclude that those results were due to blocking, are also discussed. The chapter concludes with a review of selected experiments relevant to blocking.

The blocking design

The basic blocking design is shown in Fig. 1. The design will be explained for a "go/no-go" situation in which the subject learns to respond on positive trials, where responding is reinforced, and to withhold responses on negative trials, which are nonreinforced.

Consider first the Control Group. The animals in this group are taught to discriminate between a white circle and a black triangle. Training is continued until they learn to respond when the white circle is present, and to refrain from responding when the black triangle is



TEST FOR STIMULUS CONTROL

	WHITE	BLACK
CIRCLE	○	●
TRIANGLE	△	▲

ANIMAL 1

	WHITE	BLACK
○	100	50
△	50	0

ANIMAL 2

	WHITE	BLACK
○	100	80
△	20	0

ANIMAL 3

	WHITE	BLACK
○	100	100
△	0	0

Fig. 1 A hypothetical blocking design and possible test results. Top panel shows stimuli present on positive (+) and negative (-) trials. Bottom panel shows stimuli present on test trials and examples of possible test results (number of responses to each stimulus). See text for further explanation.

present. The stimuli indicating reinforcement and nonreinforcement vary along two dimensions, shape and color; the animals can respond correctly on the basis of either of these dimensions. Such training, in which two dimensions vary together and either can be used to predict reinforcement, will be called Double Stimulus Training (DST).

Since either shape or color or both can successfully be used as cues by the Control Group, the observation that the subjects learn the discrimination does not tell us on which dimension that learning was based. In order to determine whether responding is controlled by shape or by color, a test for stimulus control is given after Phase 2. In the example shown in Fig. 1, that test involves presenting four stimuli in a mixed order and observing the number of responses occurring in the presence of each. Many responses should occur in the presence of the white circle and few in the presence of the black triangle, since those are the training stimuli. The important observation is the number of responses occurring to the black circle and to the white triangle. If a subject's responding is controlled by shape but not by color, we might find responses distributed as shown for Animal 3 in Fig. 1. If responding is controlled equally by shape and color, we would expect responses to be distributed as for Animal 1, with changes in color and changes in shape causing equal changes in responding.

Let us suppose we had arranged the stimuli so that the Control Group showed some control by each cue, as did Animal 1. Consider what might happen in the Discrimination Group. Like the Control Group, it receives DST in which both shape and color predict reinforcement. In the Discrimination Group, however, that training is preceded by Single

Stimulus Training (SST*) in which shape predicts reinforcement but color does not. The length of Phase 1 is arranged so that the Discrimination Group learns to discriminate between a gray circle and a gray triangle before the color cue is added.

Having learned to discriminate on the basis of shape in Phase 1, the Discrimination Group will have acquired stimulus control by shape before beginning DST in Phase 2. The Control Group, on the other hand, will have acquired no stimulus control by shape during Phase 1. This means that the Discrimination Group will have a greater degree of stimulus control by shape than the Control Group as the two groups begin DST (Fig. 1). If a trading relation existed between the amount of stimulus control by different dimensions, we would expect the Discrimination Group, having greater control by shape, to gain less stimulus control by color during DST. That is, the Discrimination Group would learn less about color in Phase 2 than the Control Group. Such decreased learning about the added dimension during DST will be referred to as "blocking", after a similar effect found by Kamin (1967) to occur very strongly in rats learning a conditioned emotional response. Blocking, then, will refer to a decreased learning about the second of two covarying (or redundant) cues, resulting from prior learning to discriminate on the basis of the first cue.

A demonstration of blocking requires evidence that the Discrimination Group has learned less about the added cue than the Control Group. Such decreased learning may be inferred from decreased stimulus control on a subsequent test. In order to measure whether or not blocking occurred

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* The phrase Single Stimulus Training (SST) will refer throughout this paper to discrimination training in which S+ and S- differ along only one dimension. Although the phrase is sometimes used to refer to nondiscriminative training with only a single stimulus value present, that meaning is not intended here.

in the experiment depicted in Fig. 1, a test for stimulus control is given after Phase 2. If blocking did occur, the Discrimination Group, having learned less about color, would show less control by color after Phase 2 than the Control Group. This reduced control by the added stimulus is the observation of interest in all the experiments to be reported below.

Although reduced learning about a stimulus will result in reduced stimulus control on a subsequent test, reduced control on such a test could arise from factors other than reduced learning. The distinction made here is simply that traditionally made between learning and performance. Of particular importance in this thesis is that, in order to show that one animal has learned less than another, it is important to show that the difference in stimulus control observed is not simply a function of the test situation. This will receive further discussion later in this chapter.

Explanations of blocking

Although the blocking design has been introduced here in terms of a trading relation occurring during learning, it is not felt that applying the term "trading relation" to blocking goes very far toward explaining blocking. How might it be explained? A brief sketch of two alternate explanations will be given here. Although these explanations will be discussed in more detail in Chapter 6, they are introduced here in order to suggest how interference with learning might occur in the blocking design.

First, blocking might be explained in terms of a two-stage learning process in which the first stage is the acquisition of an attention response. Assume that during Phase 1 of the experiment indicated in Fig.

1, the Discrimination Group learns not only to respond correctly to the circle and triangle, but also to "attend" to the shape of the stimuli presented to it. Since shape continues to predict reinforcement throughout Phase 2, the Discrimination Group might continue to attend to shape, which might in turn cause it to learn very little about color. On the other hand, the Control Group, not having had its attention "preset" during Phase 1, might learn something about both shape and color during Phase 2. Blocking of the acquisition of stimulus control by color in the Discrimination Group would be explained as resulting from Phase 1 training which has preset its attention on shape.

A second possible explanation of blocking is more consistent with traditional theories of learning. It emphasises the fact that the two groups may respond differently in Phase 2 as a result of different experience in Phase 1. The Discrimination Group, having learned to discriminate on the basis of shape in Phase 1, would be likely to continue responding correctly during Phase 2. This means it would make very few responses on negative trials. If nonreinforced responding on negative trials is important in establishing stimulus control, then little stimulus control by color might be acquired by the Discrimination Group during Phase 2. The Control Group, not having learned in Phase 1 to withhold responses to a triangle, would make more nonreinforced responses on negative trials and might acquire more stimulus control by (learn more about) color. Blocking of the acquisition of stimulus control by color in the Discrimination Group is explained as resulting from Phase 1 training which reduces responding on negative trials in Phase 2.

These explanations have been introduced here in order to illustrate how an interference with learning might arise in the blocking design. The experiments to be reported do not attempt to decide between these explanations. Rather, their goal is to clearly establish that blocking as defined here does occur. In order to achieve this goal, it is necessary to consider the evidence for blocking in more detail.

Alternative explanations of reduced control

The result of interest in the blocking design is that, in a test for stimulus control given after both phases of training, the Discrimination Group shows less stimulus control by the added stimulus than does the Control Group. As has been described above, this decreased stimulus control can be explained as due to decreased learning about that stimulus during DST, and that decreased learning can in turn be seen as a result of the learning about the other stimulus which occurred in Phase 1. If this explanation for the reduced stimulus control in the Discrimination Group could be established it would be evidence for blocking, and would be an example of the sort of trading relation described in Chapter 1. Before blocking can be established, however, certain other explanations for the finding of decreased control by the added cue in the Discrimination Group must be ruled out. Some of these alternative explanations will now be described.

Interaction on test

It is possible that the decreased stimulus control in the Discrimination Group represents a performance decrement rather than a learning decrement. The hypothetical experiment illustrated in Fig. 1 provides a clear example of this. Even if all the Discrimination Group subjects responded on the test as illustrated by Animal 3 in the figure, this would not necessarily mean they had learned nothing about color.

It is possible that the animals in the Discrimination Group learned as much about color during DST as did the animals in the Control Group, but the Discrimination Group was unable to reveal this control on the test due to its more powerful control by shape. We know that the Discrimination Group entered DST with more control by shape than the Discrimination Group, and it is quite possible that the Discrimination Group would still show more control by shape at the end of DST, since that Group would have had a greater total amount of training in which shape predicted reinforcement. If this did occur, the Discrimination Group might be unable to reveal any control by color that it had acquired because of its very strong control by shape. The triangular shape might produce such a weak tendency to respond that even though the change from black triangle to white triangle increased that tendency, it was still not sufficient to cause any responding. Similarly, the animals might respond at an asymptotically high rate to the black circle, so that even though the tendency to respond increased when the circle became white, this increase could not be revealed by changes in response rate.

This discussion is meant to give a general idea of what is meant by the explanation that the Discrimination Group learned as much as did the Control Group during DST, but could not reveal the stimulus control it had gained due to the occurrence of "interactions on the test". This explanation will be dealt with more fully when the results of Experiment 1 are discussed, and some additional implications underlying the interaction argument will be made explicit there. For the moment, what is important is the distinction between whether the decreased stimulus control measured in the Discrimination Group represents a learning decrement or a performance decrement. The blocking explanation for the reduced stimulus control in the Discrimination Group attributes that reduced control to a learning decrement, and an ability to rule out interactions on the test for stimulus control is required to support that explanation.

Specific irrelevance training In discussing the fourth meaning of attention in Chapter 1, a distinction was made between manipulations which might be expected to affect stimulus control directly, and those which might affect it indirectly, through a trading relation. The blocking explanation for the reduced control by color in the Discrimination Group attributes that loss to prior training which increases stimulus control by shape, not to prior training which reduces control by color in some direct way. Before concluding that the reduced control by color in the Discrimination Group was due to blocking, we would like to rule out the possibility that some aspect of the Phase 1 training given to that group decreased stimulus control by color directly. One process by which this might occur is specific irrelevance training. Suppose, for example, that the hypothetical blocking design illustrated in Fig. 1 had been modified so that during Phase 1 the circles indicating positive trials were occasionally white and occasionally black, and the triangles indicating negative trials were also varied in color. This would mean that during Phase 1 color would vary in a manner uncorrelated with reinforcement, and specific irrelevance training might occur. It is conceivable that such training might diminish the stimulus control later acquired by color through some direct mechanism - for instance, the establishment of S-R bonds of intermediate strength which could be modified only with difficulty during later discrimination training.

It is even possible that the stimulus control acquired by color could be directly reduced if both stimuli were white in Phase 1, or if both were black. We might distinguish specific irrelevance training, in which stimuli vary along a given dimension but do so in a manner uncorrelated with reinforcement, and "nonprediction training", in which stimuli simply remain constant throughout training and do not predict reinforcement. Such lack of prediction could occur with a stimulus value to be used later in training (white or black), or even with a stimulus _dimension_ to be used later (any color). Nonprediction training of this latter sort seems impossible to prevent in the experiment shown in Fig. 1, since the shapes used in SST must be _some_ color.

Even if "specific irrelevance training" does have a detrimental effect on the subsequent acquisition of stimulus control, it is possible that this effect is not a direct one, but is due to the effect of such training on a mediating attention response. It has been suggested that such training may reduce the probability of attending to the stimuli in question, and that this reduced attention explains the slower acquisition of later stimulus control (Mackintosh, 1965b, p. 134). Even if this should turn out to be so, it seems important to distinguish between (a) a reduction in stimulus control by one dimension due to prior training with that dimension irrelevant, (b) a reduction due to prior training with a second dimension relevant. We are interested here in evaluating the second possibility. It is for this reason that, despite our lack of knowledge concerning whether or not specific irrelevance training really can reduce stimulus control by some direct mechanism, the experiments reported here are designed to reduce the possibility of such training.

Other effects reducing all stimulus control In the blocking design illustrated in Fig. 1, the result of interest is decreased control by color in the Discrimination Group as compared with the Control Group. Any aspect of the Phase 1 training received by the Discrimination Group that reduced learning about both cues during Phase 2 could cause such a result. It is important to realise that in the blocking design a reduction in control by both cues might not be recognised as such, since the two groups receive different amounts of discrimination training with the pretrained cue. Suppose that something during Phase 1 reduced control by both shape and color in the Discrimination Group. Comparison of the amount of control by shape in the two groups might not reveal the reduction in the Discrimination Group, since it might be compensated for by the added training received by that Group. Even though the Discrimination Group might show more control by shape than the Control Group, there is no way for us to know whether it shows as much more control as it might have.

What might cause reduced Phase 2 learning about both cues in the Discrimination Group? One possibility is that the occurrence of any Phase 1 training might cause such reduced learning in Phase 2. If animals learn more readily early in their experimental history than later on, then the Discrimination Group might learn less about the added cue than the Control Group during Phase 2 not because of learning about the first cue in Phase 1, but because of some more general factor such as prior experience in the experimental situation.

Another possibility is that reduced Phase 2 learning about both cues occurs in the Discrimination Group as a result of some more specific aspect of its Phase 1 training. For instance, if the shape discrimination illustrated in Fig. 1 were a difficult one, the animals in the Discrimination Group would continue to respond on negative trials for several sessions before learning to discriminate during Phase 1. While doing so they would be receiving partial reinforcement with respect to responses. Since there are data that suggest partial reinforcement may decrease the stimulus control shown on subsequent tests (Hearst, Koresko, & Poppen, 1964; see Kimble, 1961, p. 340), the occurrence of such partial reinforcement in the Discrimination Group might produce an apparent blocking effect.

In Experiment 1, which is reported in Chapter 3, additional control groups are used in an attempt to control for the effect of partial reinforcement. An additional possibility is not dealt with there. It is possible that _any_ prior discrimination training causes diminished learning during DST. Does an animal learn more about the problem he is first faced with than about those which follow? If this were the case, it would again explain the reduced stimulus control by the added stimulus in the Discrimination Group without requiring the notion of blocking. Although one might wish eventually to control for this, it seems an unlikely possibility, since experiments have shown that animals frequently learn more rapidly in successive tasks rather than more slowly (Harlow, 1959; Honig, 1967). The possibility that _any_ discrimination learning reduces the stimulus control acquired in subsequent training is not controlled for in the experiments to be reported.

Experiments on blocking

An early attempt to demonstrate blocking was reported by Lashley (1942). Four rats were trained in a jumping stand to jump to the larger of two circles. When they had reached a criterion of 20 successive errorless trials, a large equilateral triangle was substituted for the large circle so that shape as well as size predicted reinforcement. Two hundred training trials with the large triangle positive and the small circle negative were given. The question of interest was whether, following training to discriminate on the basis of size, the rats would now learn about shape. To determine this, two tests were given at the completion of training. In one test, a triangle and a circle of equal area were presented; the animals jumped consistently to one door of the apparatus, right or left, showing no preference for either triangle or circle. In another test, a large circle and a small triangle were presented; the rats jumped consistently to the large circle. Since shape did not appear to control responding in either of these tests, Lashley concluded that "in spite of the opportunity for association of reaction with the differentiating shapes of the figures...,[shape] was not associated" (p. 259).

In the terminology used here, Lashley's conclusion would be stated this way: prior training to discriminate on the basis of size blocked learning about shape. On the basis of Lashley's data, however, one cannot conclude that blocking occurred. His experiment does not demonstrate that the prior training to discriminate on the basis of size reduced learning about shape, since no control group was run without such prior training. Lashley seems to assume that such a group _would_ have shown control by shape on the tests he gave: "two hundred trials is more than twice the usual practice required for learning triangle vs. circle as an initial problem" (p. 258). The assumption is unwarranted. Whether a group given 200 trials of learning with a large triangle vs. a small circle would show control by shape on the tests Lashley gave must remain an open question since (a) learning with large triangle vs. small circle might produce less control by shape than simply learning with triangle vs. circle, and (b) the tests he gave were insensitive, and unlikely to detect a small amount of learning about shape. In the first test, there was a strong competing tendency to jump on the basis of position, making it unlikely that a small amount of learning could be detected; in the second test, strong control by size would make it difficult for learning about shape to affect responding. For these reasons, although Lashley (1942) concluded that what we have called "blocking" occurred, his experiment cannot be considered to adequately support that conclusion.

In a more recent experiment, Miles (1965) used pigeons in a blocking design similar to that shown in Fig. 1. The Discrimination Group was trained in Phase 1 to discriminate positive and negative trials on the basis of the intensity of illumination of the key light ("light level"); in Phase 2 an auditory stimulus (tone vs. no-tone) was added. A Control Group received only DST. Using L_1 and L_2 to indicate different light levels, the design of the experiment may be summarized as follows:

	Phase 1	Phase 2
Discrimination Group	$\overset{+}{L_1} - \overset{-}{L_2}$	$\overset{+}{\text{Tone } L_1} - \overset{-}{L_2}$
Control Group	———	$\overset{+}{\text{Tone } L_1} - \overset{-}{L_2}$

In a test for stimulus control given after Phase 2, responding in the Control Group was controlled by presence-absence of the tone much more than was responding in the Discrimination Group. Although this result suggests that blocking occurred - that the Discrimination Group learned less about the auditory stimulus as a result of the discrimination training given in Phase 1 - other explanations for the reduced auditory control in the Discrimination Group cannot be ruled out. First, it is possible that an interaction on the test for stimulus control may have affected the results. An interaction in which reduced auditory control resulted from increased visual control seems unlikely, since four different light levels were used on the test, and presence-absence of the tone affected responding at each of these light levels more in the Control Group than in the Discrimination Group. However, responding on the test may have been influenced in yet another manner which would make such responding a poor index of learning. The evidence for auditory control on the test was a lower rate of responding with the tone absent than with it present. However, the Discrimination Group was given training in Phase 1 where responding in the absence of the tone was reinforced. This might have had some direct effect on responding during the test so that the change from tone to no-tone decreased responding only slightly in the Discrimination Group.

However, even if Miles' test findings did result from reduced learning about presence-absence of the tone in the Discrimination Group, it is possible that this reduction was due not to the discrimination training received by the Discrimination Group in Phase 1, but to some other aspect of the Phase 1 training. It might have been the case, for instance, that <u>any</u> Phase 1 training would reduce all control acquired during discrimination learning in Phase 2, or that the partial reinforcement received by the Discrimination Group early in Phase 2 was responsible for the reduction in control observed on the test. Miles' results, then, suggest that blocking may have occurred, but do not conclusively demonstrate it.

An experiment by Johnson (1966) also found changes that might be attributed to blocking. Pigeons were given DST in which both the orientation of a white line projected on the key and color of the remainder of the key predicted reinforcement. This training was either preceded or followed by SST of varying lengths. During SST only line orientation was correlated with reinforcement: the line was presented on an otherwise dark key. Tests for stimulus control given after both SST and DST showed generally increasing control by line orientation, and generally decreasing control by color, with greater amounts of SST. These relations occurred whether SST was given before or after DST. It is possible that some blocking occurred in this experiment, since giving prior training with only line orientation predicting reinforcement decreased control by color on a subsequent test. However, the experiment does not require the conclusion that this reduced control was caused by reduced learning about the added cue as a result of the prior discrimination learning, since alternative explanations for the reduction in control were not ruled out. Although an interaction on the test for stimulus control does not seem able to account for Johnson's results, the possibilities that *any* training could have caused a reduction in control on the test, or that the partial reinforcement received by the Discrimination Group contributed to the reduction in control that was observed, are not controlled for. Once again blocking may have occurred, but is not conclusively demonstrated.

A final experiment whose design concerns blocking was performed by Chase (1966). Only three of her five groups of pigeons are relevant for the comparisons to be made here. Each of those three groups received DST in Phase 2 in which both the orientation of a single black line on the key and the frequency of a 65 db tone predicted reinforcement, followed by a test for stimulus control. In Phase 1, Group T-D received training with line orientation correlated with reinforcement and tonal frequency varying in a manner uncorrelated with reinforcement; Group F-D received training with tonal frequency correlated with reinforcement and line orientation varying in a manner uncorrelated with reinforcement. A control group was given Phase 1 training with both line orientation and tonal frequency varying in a manner uncorrelated with reinforcement. All groups were given a test for stimulus control at the end of Phase 2. If prior discrimination training with tonal frequency predicting reinforcement decreased subsequent learning about line orientation during DST, Group F-D should have shown less control by line orientation than the Control Group on the test. This did not occur. Alternatively, if prior discrimination training with line orientation predicting reinforcement decreased subsequent learning about tonal frequency during DST, Group T-D should have shown less control by tonal frequency than the Control Group on the test. There was only weak evidence that this was the case. An analysis of variance showed the effect of tonal frequency to be non-significant for Group T-D, but significant at the .05 level for the Control Group. However, this difference is less convincing since the effect of tonal frequency was also non-significant for Group F-D, where it would be expected to be significant. Furthermore, an analysis of variance did not show a significant difference between groups in the effect of tonal frequency, although the difference approached significance ($.05<P<.10$).

Chase's experiment, then, did not show strong blocking. Furthermore, the possibility that interactions on the test for stimulus control affected those differences which did occur is more difficult to rule out in her experiment than in those of Johnson (1966) or Miles (1965), since tests for stimulus control by one stimulus did not use intermediate values of the other stimulus. It is interesting to compare the magnitude of the effects observed in these three experiments. To facilitate this comparison, an index of stimulus control for each experiment was created as follows: the number of responses occurring during the test when the positive value of the added stimulus was present was divided by responses occurring during the test when either the positive or negative value was present. The magnitude of this index suggests the degree to which responding was controlled by the added stimulus. The index would be 1.00 if responses occur only when the positive stimulus was present; it would be .50 if responses occurred independently of the stimulus value. In Miles' (1965) experiment, these values averaged .89 for the Control Group and .55 for the Discrimination Group. In Johnson's (1966) experiment, the equivalent indices (calculated from the average data in the group receiving DST only and the group receiving the longest period of SST prior to DST, his groups 16 and 5) were .93 and .64. In Chase's (1966) experiment, the equivalent indices (estimated roughly from her Figs. 19 and 21, for the U-D and T-D Groups) were .65 and .56.

In each experiment the differences in the degree of stimulus control by the added stimulus were in the direction which would be predicted if blocking had occurred. However, much smaller differences between groups occurred in Chase's (1966) experiment than in the other two experiments. This fact is especially interesting for the following reason: it is only in Chase' experiment that the possibility of reduced control resulting from <u>any</u> training, or from partial reinforcement which occurs early in discrimination training, can be ruled out. These possibilities can be ruled out in Chase's experiment since her control group, by receiving training with both stimuli varying in a way uncorrelated with reinforcement in Phase 1, effectively controls for them.

The observation that two experiments find large differences, but do not control for certain factors which might cause these differences, while a third experiment controls for these factors and finds much smaller differences, suggests that these factors may indeed be causing some part of the differences observed. This between-experiment comparison is certainly no more than suggestive, since many other differences exist between the experiments. However, a more direct test of the possibilities that reduced control results from <u>any</u> training, or from the partial reinforcement received in the Discrimination Group, should be of interest. In the absence of such direct tests, attempts should be made to control for these factors, so that an observed reduction in control is not attributed incorrectly to the <u>discrimination</u> training received in Phase 1, leading to a false conclusion that what has been called blocking has been demonstrated.

Summary of Chapter 2

In this chapter, the blocking design was described and the possible finding of "blocking" was defined as a decreased learning about the second of two covarying cues resulting from prior learning to discriminate on the basis of the first cue. Such reduced learning should result in decreased stimulus control by the second cue in a subsequent test for stimulus control. However, it was pointed out that such decreased control might be due to other factors than blocking. In order to conclude that blocking did indeed occur, three alternative explanations for the decreased control must be eliminated. These alternative explanations include the possibility of an interaction on the test for stimulus control, the occurrence of specific irrelevance training or nonprediction training, and the possibility of other effects reducing all stimulus control. Four experiments were reviewed which suggested that blocking had occurred but did not conclusively demonstrate it, since they failed to control for one or more of these three factors. We turn now to a blocking experiment whose design enabled evaluation of these factors.

CHAPTER 3

Experiment 1

Each of the four experiments described in this thesis was based on the blocking design. Each experiment used a trial procedure in which pigeons learned to peck a lighted disk ("key") on positive trials in order to receive food reinforcement, and ceased pecking on negative trials, when reinforcement could not be obtained. In all cases the occurrence of a trial was indicated by the lighting of the key.

In Experiment 1* an attempt was made to block the acquisition of control by auditory cues in the pigeon by training a prior discrimination based on visual cues. In addition, the experiment was designed so that the possible occurrence of interactions on the test, specific irrelevance training, and other effects reducing all stimulus control in the Discrimination Group could be evaluated.

DESIGN

The design of the experiment is shown in Fig. 2. Four groups of pigeons were first trained to peck a key when it was lit with white light, and then given two phases of training. During this training positive and negative trials could be distinguished on the basis of a

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* Experiment 1 was actually performed last. It is reported first to allow more concise exposition.

GROUP	PRELIMINARY TRAINING (5 SESSIONS)	PHASE 1 (15 SESSIONS)	PHASE 2 (11 SESSIONS)	TEST FOR STIMULUS CONTROL
DISCRIMINATION GROUP (N=6)	S^{+}Ⓦ	S^{+}Ⓡ - S^{-}Ⓖ	T^{+}Ⓡ - N^{-}Ⓖ	
NOT RUN GROUP (N=6)	S^{+}Ⓦ	NOT RUN	T^{+}Ⓡ - N^{-}Ⓖ	
S+ ONLY GROUP (N=6)	S^{+}Ⓦ	S^{+}Ⓡ - NO TRIAL	T^{+}Ⓡ - N^{-}Ⓖ	
PARTIAL GROUP (N=6)	S^{+}Ⓦ	S^{+}Ⓡ - S^{-}Ⓡ	T^{+}Ⓡ - N^{-}Ⓖ	

Fig. 2. Stimuli present during positive (+) and negative (-) trials in Experiment 1. The key was lit on each trial; it could be illuminated with white (W), pale red (R), or pale green (G) light. The auditory condition during a trial could be tone (T), noise (N), or silence (S). Between trials the silence condition prevailed and the key remained unlit.

visual cue (pale red vs. pale green key light) or the visual cue in addition to an auditory cue (tone vs. noise). For all groups, the training given in Phase 2 was DST, with both the visual and the auditory cue predicting reinforcement. The Discrimination Group was taught to discriminate on the basis of the color cue in Phase 1, while the Not Run Group received no training during that phase. These two groups constitute a basic blocking design similar to the one presented at the beginning of Chapter 2. If blocking occurred, the Discrimination Group, having stronger visual control as it entered DST, would learn less about the auditory cue during Phase 2, and would show less auditory control on the subsequent test for stimulus control.

The remaining two groups were the S+ Only and the Partial Group. The S+ Only Group received only positive trials during Phase 1, and the Partial Group received partial reinforcement by being exposed to only a single type of trial and receiving reinforcement on a random 50% of those trials. These groups were meant to control for two possible alternative explanations of lower auditory control in the Discrimination Group. First, if it were the case that <u>any</u> training given in Phase 1 reduced subsequent control, then each of the other three groups would show less control than the Not Run Group. Second, if the partial reinforcement received by the Discrimination Group during its Phase 1 training led to diminished control, then the Partial Group would also be expected to show less control than the Not Run Group. On the other hand, if the Discrimination Group showed less auditory control than any of the other three groups, these alternative explanations for its reduced control would be ruled out.

The design also controlled for the possibility that specific irrelevance training or even nonprediction training (with a stimulus later to be used present but not predicting reinforcement), might cause reduced control by the auditory cue in the Discrimination Group. First, no auditory change occurred to indicate trials during Phase 1 for the Discrimination Group. The background auditory value ("silence") remained constantly present throughout all sessions for all groups prior to Phase 2. Second, even if the presence of silence could be considered detrimental to the later acquisition of control because it was a value on the auditory dimension and it did not predict reinforcement, the Partial Group controlled for this since silence was nonpredictive of reinforcement for it also. If the auditory control shown by the Discrimination Group was less than that shown by the Partial Group, the possibility of a direct reduction in control due to specific irrelevance training or to nonprediction training could be ruled out.

Finally, although the possibility of an interaction on the test for stimulus control was not directly controlled for, the test was constructed so that such an interaction could be detected. The possibility of an interaction will be considered in detail when the results of the experiment are described.

METHOD

Subjects and Apparatus

Subjects Twenty-four male white King pigeons maintained at 75-85% of their free feeding weight served as subjects. They were 5-6 years old and without experimental history.

Apparatus Three standard Lehigh Valley Electronics one-key pigeon chambers, Model 1318, were located in a small room. On one wall of each chamber, centered 10½" above the chamber floor, was a key which closed an electrical contact when pecked and so allowed recording of the pigeon's pecks. Beneath the response key was an opening through which the pigeons could reach food when a tray containing grain was raised into position. Reinforcement consisted of raising the tray for 3 sec and simultaneously lighting the tray opening. To the left of the response key was a loudspeaker through which auditory stimuli could be presented. Since tone and noise stimuli were used in each of the chambers, attempts were made to decrease sound transmission from chamber to chamber by separating the chambers physically and by supporting them with sound insulating material.

Auditory stimuli Three auditory stimuli were available in each box; these will be called tone, noise, and silence. The tone was a 1000 cps, 82 db re SPL tone generated by a General Radio Co. audio oscillator type 1311-A; the noise was 76 db white noise generated by a Grason-Stadler model 901-B noise generator; and silence was the condition prevailing when neither of these were present. The ventilating fans remained on in the silence condition, generating a background noise of 60-65 db. All stimulus measurements were made with the experimental chamber closed, using a General Radio Company Sound Survey Meter Type 1555-A placed with the receiving end toward the response key and 4" directly in front of it. Tone and noise levels were monitored daily and adjusted as necessary.

Visual stimuli The translucent key in each box could be lit with white, red, or green light by means of filtered bulbs located behind the key. The white light was obtained by lighting the white-filtered bulb (Sylvania #24E SB) supplied by the manufacturer. The red and green key illuminations were obtained by lighting the white-filtered bulb and, in addition, partially lighting the red- or green-filtered bulbs supplied. To reduce the localization of different colors on different parts of the key, a set of diffusing screens was placed between the bulbs and the key. The resulting pale red and pale green key illuminations could be distinguished from the white illumination only with difficulty by each of three human observers.

General illumination was provided in each chamber by a houselight located 2½" above the center of the response key. Houselights remained on throughout each experimental session. The houselights and key lights were powered by a DC supply separate from that used by the control equipment in order to isolate them from changes occurring in that equipment.

Control apparatus The control apparatus was located outside the room containing the experimental chambers. It made use of a stepping switch that essentially fed a single trial successively to each of the three chambers. This allowed large elements of the control apparatus to be used for each of the three chambers. Each chamber was fed stimuli determined by its own teletype tape reader, so that orders of stimulus presentation could be arranged independently in each chamber. Recording was accomplished by counters, an Esterline-Angus operations recorder, and a Sodeco Decaprint printout counter that could code what stimulus combination was presented in each chamber.

Procedure

The experiment used a discriminated trial procedure. Between trials the houselight remained on but the key was unlit; neither tone nor noise was present. Responses occurring between trials had no effect and were never reinforced.

Trials were indicated by the lighting of the key, and were terminated (key light off) when 7 seconds had elapsed or when a response unit (4 responses) had been completed. If the trial was a positive trial the completion of a response unit led to reinforcement (3 sec access to grain) and terminated the trial; if it was a negative trial the completion of a response unit ended the trial but no reinforcement occurred. The time between trial onsets averaged 50"; it was frequently only 40", and occasionally as long as 85".

Each pigeon was assigned to one of the experimental chambers and was run in it daily at approximately the same time. Sets of three pigeons were run concurrently in the three chambers, and the pigeons in any set were always members of the same Group. Each Group was composed of two such sets, so that the six Ss in each Group included two run in chamber 1, two in chamber 2, and two in chamber 3.

Preliminary training In the first session the pigeons were trained to peck the key by the method of successive approximation. Reinforcement was presented for responses which more and more closely resembled a peck, until finally only responses closing the electrical contact behind the key were reinforced. Throughout this training responses were reinforced only when the key light was on. During the second and third sessions the number of responses required to complete a trial and obtain reinforcement was increased from 1 to 4, where it remained for the rest of the experiment. The second through fifth sessions consisted of 60 positive trials only. This preliminary training was meant to increase response strength so that acquisition of the discrimination could be seen as a decrease in response strength to stimuli on the negative trial without simultaneous increases in strength on the positive trial.

Phase 1 Starting with the sixth session the groups were given the different sorts of training indicated in Fig. 2. The Discrimination Group received 80 trials per session. Half of these were positive and half were negative; they were presented in a mixed order so that an equal number of positive and negative trials was presented in each half of each session. Three different trial orders were used, and orders were changed daily for each pigeon. This practice was followed throughout the experiments reported here whenever more than one trial type occurred. Orders of stimulus presentation were arranged so that the occurrence of a particular sort of trial in one experimental chamber never predicted anything about the trials occurring in other chambers.

Stimulus orders for animals in the S+ Only and Partial Groups were the same as those in the Discrimination Group. In place of negative trials with the key green, however, the Partial Group received negative trials with the key red, so that negative trials could not be distinguished from positive trials. The S+ Only Group received 40 positive trials only; no trial was presented at times when the Discrimination or Partial Groups would have received a negative trial.

The Not Run Group received no training during Phase 1. Pigeons in that group remained in their home cages except for weighing; they were maintained at 80% weight.

Between sessions 15 and 16, after 10 days in Phase 1, the visual stimuli were adjusted so that both the red and green lights were very slightly more saturated. This change was made in order to improve discrimination performance in the Discrimination Group.

Phase 2 Starting with the 21st session, all groups received 11 sessions of discrimination training with both the auditory cue and the visual cue predicting reinforcement.

Test for stimulus control A test for stimulus control was given during sessions 32 and 33. Three auditory stimuli (tone, noise, and silence) and three visual stimuli (red, green, and white) were used on trials during the test, in all nine combinations. Nine different mixed sequences of the 9 stimulus combinations, for a total of 81 trials, were given in each session. Trials were programmed as they had been previously, but were terminated only after 7 sec had elapsed - responding had no effect on trial length during the test*. Reinforcement never occurred during the test.

RESULTS**

Learning results

First the amount of intertrial responding will be reported and discussed. The results for Phases 1 and 2 will then be reported.

Intertrial responding The median number of ITRs per session

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[*] This change was suggested by Robert Sainsbury.

[**] Detailed learning and test data for each of the experiments is given in the appendix. All analyses summarized in the text are presented in more detail in the appendix.

during Phases 1 and 2 ranged from 0 to 6 for individual birds; ITRs during the tests for stimulus control were more frequent, averaging 9.4 per session. Only one bird made more than 17 ITRs in any non-test session, or more than 27 ITRs in a test session. That bird (#33) made a normal number of ITRs except in his last 6 sessions, when ITRs rose substantially, reaching a maximum of 455 in session 29. Although #33 also made more ITRs in test sessions than any other bird (41 and 25), these were of the same order of magnitude as those of other birds.

Although some of these numbers may sound high, it should be recalled that the birds respond during the trials at a rate of about 60 responses per minute; they have about 56 minutes in each session during which they can make ITRs. Furthermore, the major part of the numbers reported above is probably contributed by "carryover" responses, made within a second after the key light went off at the end of a trial. Finally, although the effect of intertrial responses is not known, it is possible that even substantial amounts of intertrial responding might have little effect on performance during the trials, since the discrimination of the trial stimuli from the intertrial stimulus should minimize generalization between trial and intertrial stimuli.

Phase 1 During Phase 1 the Discrimination Group learned to discriminate the color of the key light. The pigeons had been given only positive trials during preliminary training, and they continued to respond to almost all positive trials during Phases 1 and 2. Discrimination learning is therefore indicated by a reduction in responding to negative trials. Fig. 3 shows that the number of response units completed on negative trials in the Discrimination Group dropped from the maximum of 40 to a low level

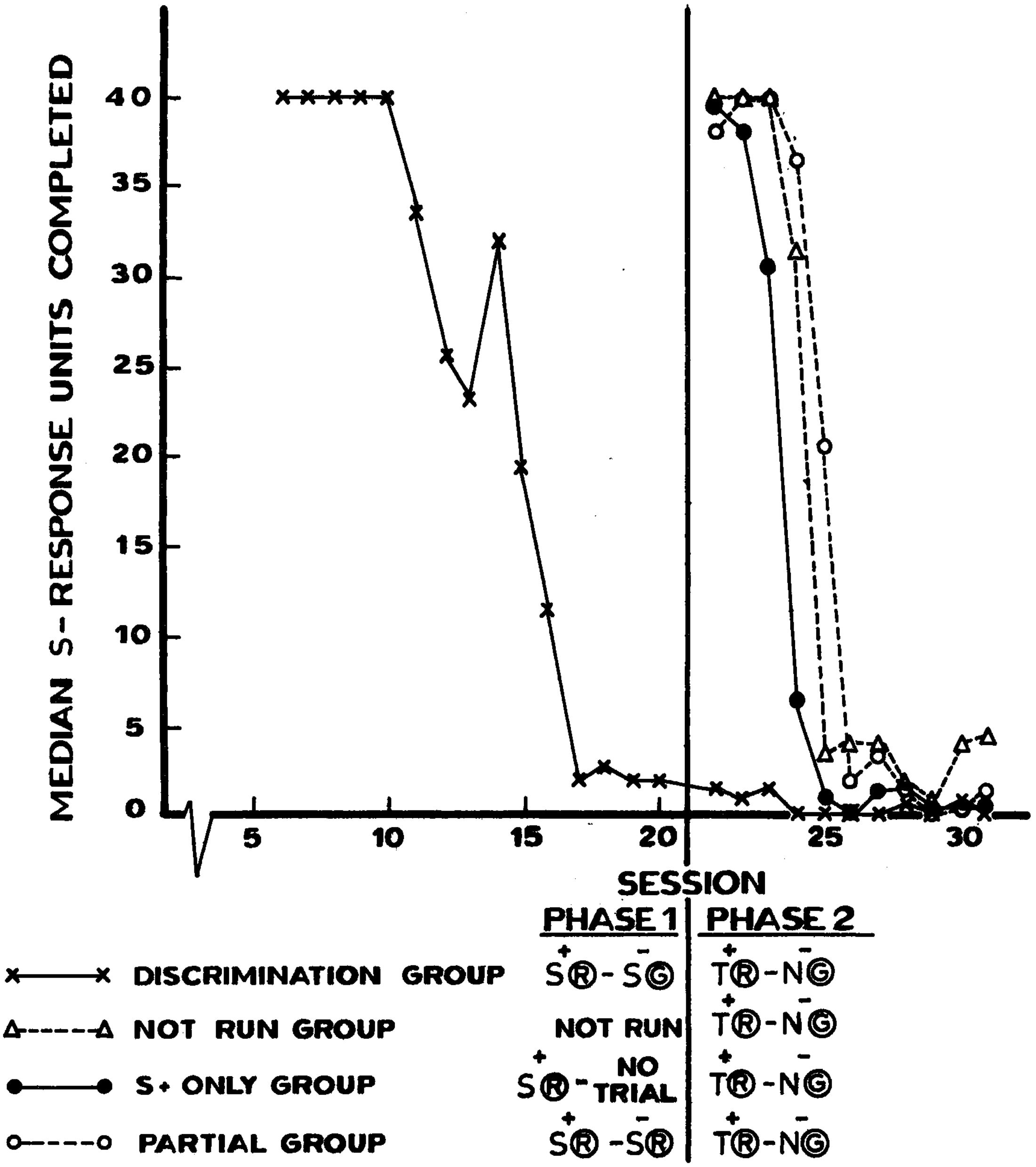

Fig. 3. Median number of response units completed on negative trials in Experiment 1. Only data for the Discrimination Group are shown in Phase 1.

during Phase 1. This was true for 5 of the 6 Ss. Each of these Ss completed response units in at least 119 of the 120 positive trials in the last 3 sessions of Phase 1; none of them completed more than 5 response units during the 120 negative trials in those sessions. The sixth S showed no signs of learning during Phase 1, and data from that S will be omitted from all further results to be described.

The S+ Only Group continued to respond on the positive trials presented to it during Phase 1. Each of the 6 Ss completed response units on at least 117 of the 120 positive trials in the last 3 sessions of Phase 1. The Partial Group responded to both positive and negative trials throughout Phase 1. Five of the 6 Ss completed response units on at least 119 of the 120 positive trials and on all of the 120 negative trials in the last 3 sessions of Phase 1; the sixth S completed response units on about half the positive and half the negative trials.

During Phase 1 the Discrimination Group continued responding on positive trials and ceased responding on negative trials, the S+ Only Group received positive trials only and responded on them consistently, and the Partial Group continued responding on both positive and negative trials. The amount of nonreinforced responding in the Discrimination Group was between that in the Partial Group and that in the S+ Only Group. The Not Run Group received no training.

Phase 2 During Phase 2 the pigeons in the Discrimination Group continued to make very few responses on negative trials. The Ss in other groups began to discriminate in from 2 to 7 days. Fig. 3 shows the number of S- response units completed in each Group.

The Not Run and Partial Group did not differ significantly in rate of learning. However, the S+ Only Group learned significantly faster than the Not Run Group or the Partial Group. The first day during which at least 5 less response units were completed on negative trials than on positive trials was less for the S+ Only Group than for the Not Run Group ($P<.01$)* or the Partial Group ($P<.05$), indicating that learning began sooner in the S+ Only Group. The largest difference between groups occurred during the third day of Phase 2; the number of response units completed on negative trials on that day was less for the S+ Only Group than for the Not Run or Partial Groups ($P<.01$ for each comparison). Finally, the total number of response units completed on negative trials throughout Phase 2 was also less for the S+ Only Group ($P<.01$ and $P<.05$ for the two comparisons).

The Discrimination Group made fewer nonreinforced responses throughout Phase 2 than any other Group. The 5 Ss in the Discrimination Group completed from 2 to 43 response units on negative trials throughout Phase 2; pigeons in other groups completed from 49 to 259 such response units. This lack of overlap makes comparison of the Discrimination Group with each of the other groups significant at the .01 level.

Indices of stimulus control

The main questions now before us involve the degree to which different groups of animals were controlled by the auditory stimuli. In order to evaluate these questions we need an index that will summarize the degree of auditory control for each animal. Several alternative indices

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* Unless otherwise indicated, the Mann-Whitney U test is used for all statistical comparisons. The U test considers the degree of overlap between groups when the scores are ranked, and does not require more than ordinal measurement (Siegel, 1956). All probabilities given are based on a two-tailed test.

are used in describing the results of the experiments reported here. These indices will now be considered in some detail.

In the tests for stimulus control, the three auditory and three visual stimuli were presented in all nine combinations. To analyze the results of the tests, the stimuli were arranged in a 3 x 3 table, and the number of responses occurring to each stimulus combination was entered in the body of the table. An example of such a table is shown in Table 1.

With the results arranged in this way, the right hand marginal values of the table show total responses on trials when a given auditory stimulus was present, and the marginal values along the bottom of the table show total responses when a given visual stimulus was present. We can get some idea of control by visual and auditory stimuli by looking at these marginal values. If total responses when tone was present are much greater than responses when noise was present, for instance, we know that the auditory stimulus strongly controlled the response. As an index of the strength of this control, the value T/(T+N) was used, where T stands for total responses on trials with tone present, and N stands for total responses on trials with noise present. This index is 1.0 if responses occurred only when the tone was present; it is .5 if responses were distributed independently of the auditory stimulus. The corresponding index of visual control is total responses to the red key divided by total responses to the key when red or green. This index is symbolized Ⓡ/ (Ⓡ+Ⓖ).

The index T/(T+N) includes responses on red trials, green trials, and white trials. In addition to this overall auditory index, indices were computed which considered these trials separately. For instance, an

TABLE 1

RESPONSES TO DIFFERENT TEST STIMULI AND DERIVED INDICES OF CONTROL. (RESPONSE ENTRIES FROM SUBJECT #21, EXPERIMENT 1.) THE TRIAL ANALYSIS IS NOT PRESENTED.

	Ⓡ	Ⓖ	Ⓦ	
T	63	20	67	150
N	13	0	1	14
S	51	6	23	80
	127	26	91	244

MULTIPLICATIVE INDICES

overall auditory index: T/(T+N) = 150/164 = .915

auditory index in white: TⓌ/(TⓌ+NⓌ) = 67/68 = .985

overall visual index: Ⓡ/(Ⓡ+Ⓖ) = 127/153 = .830

visual index in silence: SⓇ/(SⓇ+SⒼ) = 51/57 = .895

ADDITIVE INDICES

overall auditory index: T-N = 150-14 = 136

auditory index in white: TⓌ-NⓌ = 67-1 = 66

overall visual index: Ⓡ-Ⓖ = 127-26 = 101

visual index in silence: SⓇ-SⒼ = 51-6 = 45 index of auditory control which considered only trials with the key white would be TⓌ/ (TⓌ+ NⓌ). Similarly, an index of visual control which considered silence trials only would be SⓇ/ (SⓇ+ SⒼ).

The indices which have so far been described will be termed "multiplicative indices". This is because they are based on the assumption that stimulus control exerts its effect in a multiplicative manner; it is assumed that the effect of changing from one stimulus to another is to multiply the number of responses by a certain constant. Although there is some support for this assumption (Dews, 1962, p. 374; Cumming, Berryman, & Nevin, 1965), it is not a demonstrated fact, and one might assume instead that stimulus changes affect the number of responses occurring by adding or subtracting responses. Because of this possibility, additive indices of stimulus control were also considered. For example, the overall additive index of auditory control, T-N, indicates the additional responses which occur when the auditory stimulus is a tone rather than a noise. As with the multiplicative index, an additive index which considers white trials only, TⓌ- NⓌ, can also be used. For each of these auditory indices, of course, there is a parallel index of visual control.

One final index of auditory control resulted from a trial by trial analysis of the data from the test for stimulus control. Throughout the test, each successive sequence of nine test trials was considered separately. In each sequence, each of the three T trials was compared with its matched N trial (for example, TⒼand NⒼwere compared) to see whether there was a difference in the number of responses occurring to them. Considering all such cases in which there was a difference, it was then determined in what proportion of these cases there were more responses to the T trial than to the corresponding N trial. The magnitude of this proportion should be a function of the strength of auditory control. Further, the proportion should not be greatly affected by an interaction between auditory and visual control of the sort described in Chapter 2, since the analysis disregards sequences in which responding is asymptotic.

The multiplicative indices are the major indices used in reporting the results of these experiments. Their use is consistent with the common practices of normalizing generalization gradients by dividing responses to each stimulus value by responses to S+, and using response ratios as an index of discrimination. However, all major conclusions made here using the multiplicative indices are also supported by the use of the additive indices (both indices are reported fully in the appendix). This close agreement between additive and multiplicative indices is not surprising, since the indices are not independent.

Test results

If blocking occurred, the Discrimination Group should have shown less auditory control on the test for stimulus control than any of the other groups. Multiplicative indices of auditory control are shown in Table 2. According to this index, the Discrimination Group did indeed show less auditory control than the other three groups. The largest difference was between the Discrimination Group and the S+ Only Group ($P<.01$), but the Discrimination Group also showed significantly less control than the Not Run and Partial Groups ($P<.05$ in each case).

The Groups also differed with respect to visual control. A scatter diagram showing the degree of auditory and visual control in each subject is shown in Fig. 4. In general, the Discrimination Group showed

TABLE 2

TEST RESULTS FOR EXPERIMENT 1: INDICES OF AUDITORY CONTROL

GROUP AND SUBJECT		INDEX OF CONTROL: T/(T+N)	
Discrimination Group	#17	.561	Mean = .578
	#18	.486	
	#37	.574	
	#40	.610	
	#42	.658	
Not Run Group	#27	.620	Mean = .752
	#29	.823	
	#30	.577	
	#47	.817	
	#48	.695	
	#49	.980	
S+ Only Group	#21	.915	Mean = .904
	#22	.833	
	#23	.875	
	#43	.940	
	#44	.921	
	#46	.939	
Partial Group	#6	.710	Mean = .719
	#74	.773	
	#16	.627	
	#32	.576	
	#33	.833	
	#34	.793	

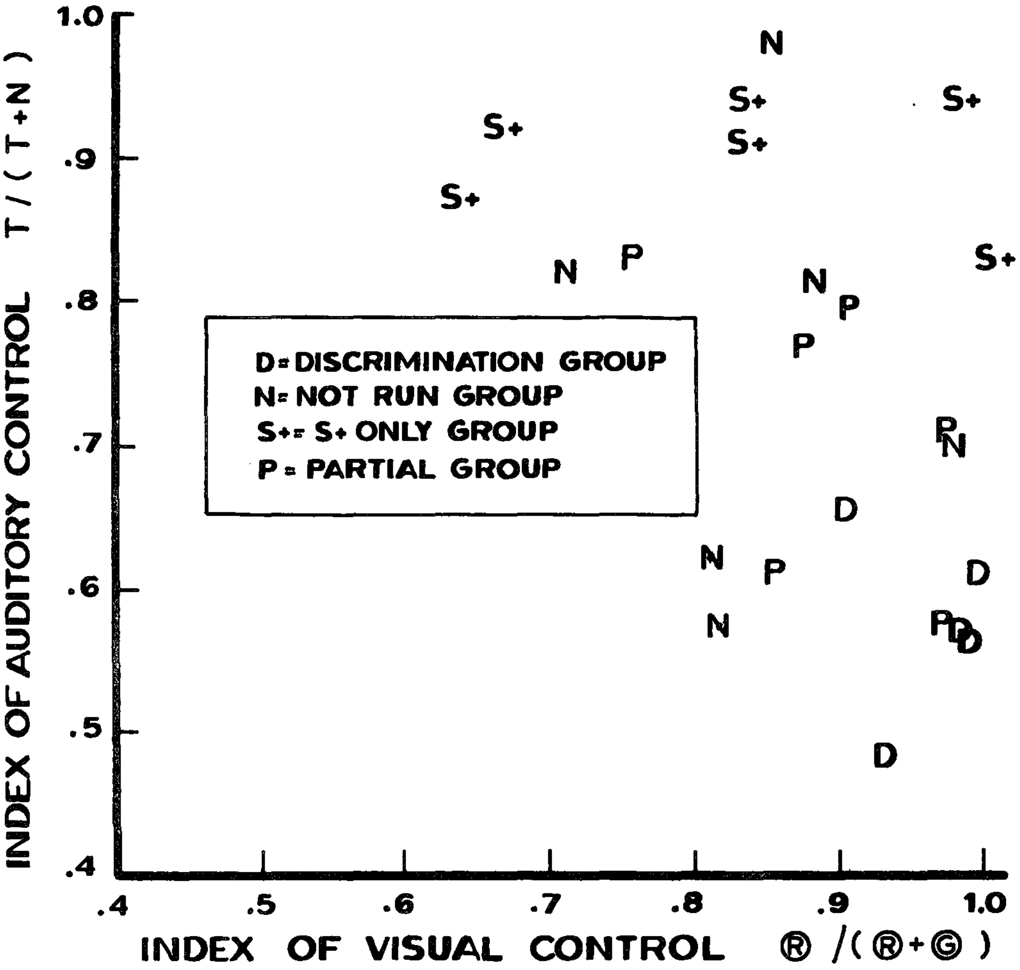

Fig. 4. Scatter diagram showing degree of auditory and visual control in each subject in Experiment 1, as indicated by overall multiplicative indices.

high visual control and low auditory control, while the S+ Only Group showed somewhat lower visual control and significantly higher auditory control. The Not Run and Partial Groups fell somewhere in between, with _Ss_ in the Not Run Group showing an especially large degree of variability.

When the additive instead of the multiplicative indices were used, the same pattern of results emerged, but with slightly lower levels of statistical significance. The average auditory control shown by the Discrimination Group was again less than that in any other Group. It was significantly less than that in the S+ Only Group ($P<.01$) or the Partial Group ($P<.05$).

The trials analysis of auditory control showed a large degree of variability within groups. Once again, however, the Discrimination Group showed less auditory control on the average than any other group. This difference was significant only in the case of the S+ Only Group ($P<.01$).

DISCUSSION

According to the multiplicative index, the Discrimination Group showed significantly less auditory control than the Not Run Group. Was this reduced control due to blocking, or can it be accounted for by one of the alternative explanations described in Chapter 2? (a) Would _any_ Phase 1 training produce such a reduction in auditory control? The S+ Only and Partial Groups showed more auditory control than the Discrimination Group, so this is not the case. (b) Was the reduction in auditory control due to partial reinforcement in Phase 1? The Partial Group did show less auditory control than the S+ Only Group, so it is possible that the partial reinforcement received by the Discrimination Group during Phase 1 caused some loss in stimulus control. However, the fact that the Discrimination Group showed still less auditory control than the Partial Group shows that not all of the reduction in control in the Discrimination Group can be attributed to partial reinforcement.

(c) Was the reduced auditory control in the Discrimination Group a result of "nonprediction training" with silence not predicting reinforcement? It was not, since the Partial Group, which also received such nonprediction training, showed more auditory control than the Discrimination Group.

Finally, we must consider the possibility that the decreased auditory control found in the Discrimination Group resulted from an interaction during the test for stimulus control. Is it possible that the Discrimination Group learned as much about tone-noise as did the other groups, and that its low index of auditory control was actually an indirect result of increased visual control? The importance of this possibility requires us to consider it in some detail. Most of our evidence concerning it is indirect, however, and the argument will be somewhat complex. Our conclusion will be that it is very unlikely that such an interaction accounts for the reduced auditory control found in the Discrimination Group.

The possibility of interaction on the test

Let us begin with an explicit statementof how an interaction on the test for stimulus control might be expected to exert its effect. Consider again the ninefold table shown in Table 1 (p.56). Suppose that increased control by the visual stimuli had the effect of leading the animal to respond at a very high rate when the key light was red.

If the animal were responding at an asymptotically high rate, changes in the value of the auditory stimulus might be able to affect his response rate only slightly. Similarly, it might be the case that no responding occurred to the green key whether tone or noise was present, so that changes in auditory stimuli would not affect response rate on trials with the key green. A situation such as this could mean that the observed stimulus control by the auditory stimulus would be low, not as a result of decreased learning about the auditory cue, but because of strong visual control which prevented that learning from affecting responding on the test.

Fig. 5 gives an explicit example of the way such an interaction might work in this experiment. Response rate is shown as a function of trial stimulus for each of two animals, one with strong and one with weak visual control. The animal with weak visual control is also controlled by auditory stimuli, as indicated by the arrangement of trial stimuli along the abscissa. For the animal with strong visual control, however, the change from tone to noise is not always accompanied by a change in response rate, since response rate when the key is red or green is at an asymptotic level. This in turn could cause the overall indices of auditory control (both multiplicative and additive) to be lower in the animal with strong visual control. Such an effect is what will be meant here by an interaction on the test for stimulus control.

The interaction argument as it applies to this experiment is this. Because of its training in Phase 1, the Discrimination Group is more strongly controlled by visual stimuli than are the other groups. During Phase 2 the Discrimination Group also learns about the auditory stimuli. However, it shows little auditory control during the test for stimulus

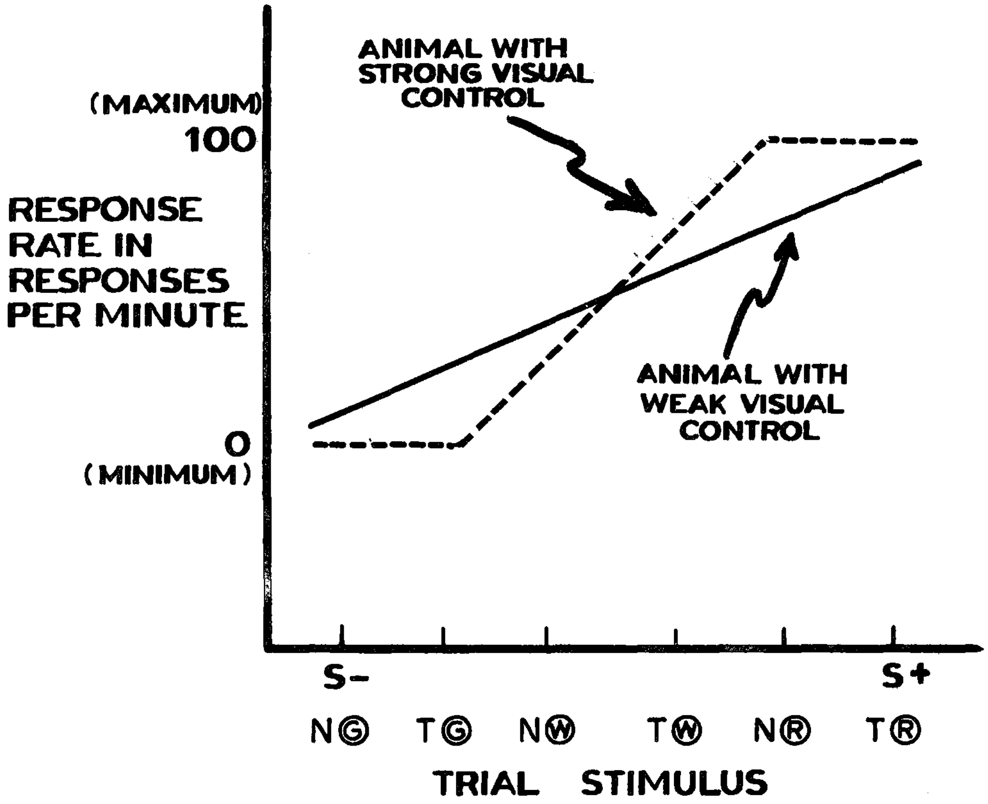

Fig. 5. Illustration of an idealized relation between stimuli and response rate.

control due to its very strong visual control. This is because responding in Red, or responding in Green, or both, are at asymptotic levels and are insensitive to changes in the auditory stimulus. What are the implications of this argument?

The first implication is that the overall auditory index should decrease as visual control increases. Fig. 4 shows that there is no strong trend in this direction within groups. Within-group correlations between the auditory and visual multiplicative indices of control, using the Spearman rank correlation coefficient, were -.10, +.03, -.03, and -.49. Only three of the four correlations are in the correct direction, only one is large, and none is statistically significant. No overall correlation was taken since considering all subjects together confounds the possibility of interaction with the experimental manipulations - such as training given to the Discrimination Group which was expected to increase visual control and decrease auditory control.

The second implication concerns the relation between auditory indices computed considering red trials only, considering green trials only, and considering white trials only. Responding on white trials was intermediate between responding on green trials and responding on red trials in 22 of the 23 birds ($P < .001$ by a sign test). If the argument for interaction is correct, what should this mean?

First, it means that the auditory index in white should show stronger stimulus control than the auditory indices in red or in green (see Fig. 5). This was not the case. Although the multiplicative auditory index in red was less than the index in white in 19 of 23 cases ($P < .01$), the index in green was greater than the index in white in 14 of

17 cases (P<.02).*

Second, let us consider in more detail the fact that the auditory index in white was stronger than that in red. Was this due to the sort of interaction described above? If so, we would expect that the auditory index in red would be less in animals with stronger visual control. The auditory index in white, however, should be little affected by the level of visual control. This means that the differences between the indices in white and red should be greater in animals with stronger visual control. To determine if this was the case, Spearman rank correlation coefficients were calculated between (a) the multiplicative index of visual control and (b) the difference between the multiplicative index of auditory control considering white trials only and that index considering red trials only. That correlation was -.10, -.37, -.14, and +.20 in the four groups. Only one of the four correlations is in the correct direction and it is neither large nor statistically significant.

There is one more possible contention which must be dealt with. Most of the implications of an interaction explanation which we have dealt with are based on the assumption that the multiplicative index of auditory control in white would be less affected by increased visual control

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* This increase in the multiplicative index of auditory control from red to white to green is possibly due to the decreasing number of responses entering into the index. It might be related to the finding that, when normalized by dividing responses to each stimulus by responses to S+, generalization gradients steepen as responding decreases during extinction (Friedman & Guttman, 1965; Jenkins & Harrison, 1960). However, in this experiment, overall multiplicative indices of auditory and visual control did not increase significantly from the first test day to the second (the auditory index increased in only 15 of 23 _S_s, the visual index increased in only 14 of 22 _S_s).

than would the auditory indices in red or green. Suppose this were not the case? What if increased visual control in the discrimination group had the effect of "locking in" response rate to all visual stimuli, white as well as red and green? Although this is an empirical possibility, it is not the same sort of interaction as we have considered above. If such "locking in" occurred, it might be difficult to claim that the lack of auditory control in the Discrimination Group was due to a mere performance difference and not to a learning difference. Any claim that an effect is a performance effect and not a learning effect rests on our ability to find some situation in which the learning supposed to have occurred can be revealed. If no such situation exists, the distinction becomes meaningless. An effect of "locking in" response rate to all visual stimuli, to the decrement of auditory stimuli, would be evidence for the sort of attention phenomenon the experiment was designed to explore.

Finally, the entire interaction explanation of reduced auditory control in the Discrimination Group depends on that group having stronger visual control than the other groups. Although on the average this was the case, the multiplicative index of visual control for the Discrimination Group was not significantly more than that for the S+ Only Group or that for the Partial Group. It seems as though the increase in visual control for the Discrimination Group was not as strong an effect as the decrease in auditory control. It is difficult to see how one effect can be explained as an indirect result of another, somewhat weaker effect.

Our conclusion is this. We are unable to reject entirely the possibility that the overall auditory index was affected by the strength of an animal's visual control. However, several lines of evidence suggest that this effect, if it occurred at all, could not have been strong. It is very unlikely that interaction on the test accounts for more than a small part of the reduction in auditory control found in the Discrimination Group.

Use of auditory indices in white

The foregoing analysis has shown that it is very unlikely that an interaction on the test accounts for the decreased auditory control in the Discrimination Group. Even if such an interaction did occur, it would be unlikely to affect the indices of control which consider white trials only (see Fig. 5). Those indices continue to indicate decreased auditory control in the Discrimination Group, however, showing once again that an interaction on the test for stimulus control does not explain this finding. By both the multiplicative and additive indices which consider white trials only, the Discrimination Group shows less control than the S+ Only Group ($P<.01$), the Partial Group ($P<.05$), and the Not Run Group. Although this last difference is not statistically significant, it is the least important of the three comparisons. The first two comparisons alone enable us to conclude that reduced auditory control in the Discrimination Group occurs, and that this reduced control is not due to *any* Phase 1 training, to partial reinforcement in Phase 1, or to nonprediction training in Phase 1. The use of auditory indices which consider white trials only, then, again supports the conclusion that reduced control in the Discrimination Group did indeed result from the discrimination training given that group in Phase 1 - that is, that blocking occurred.

SUMMARY OF EXPERIMENT 1

Four groups of 6 pigeons were used to examine the possibility that the acquisition of control by an auditory cue could be blocked by prior training to discriminate on the basis of a visual cue. The auditory cue was tone vs. noise, while the visual cue was pale red vs. pale green illumination of the key which the pigeons pecked. Two phases of training were given. The groups received different sorts of training in Phase 1; in Phase 2 all groups received training in which both the auditory and the visual cue predicted reinforcement. On a test for stimulus control given after Phase 2, a group trained to discriminate on the basis of key color in Phase 1 showed less auditory control than a group which received no training in Phase 1. Two additional groups showed that this decreased auditory control in the first group was not due to the receipt of *any* training during Phase 1, the occurrence of partial reinforcement in Phase 1, or nonprediction training with an auditory stimulus present but not predicting reinforcement; detailed analysis of the test data showed it was not due to an interaction on the test for stimulus control.

CONCLUSION

Experiment 1 demonstrates that the acquisition of auditory control in the pigeon can be blocked by prior training to discriminate on the basis of a visual cue. The Discrimination Group was found to have less auditory control than each of three other groups, The ruling out of alternative explanations for this result enables the conclusion that it was caused by a decreased learning about the auditory cue in Phase 2 for the Discrimination Group. This conclusion leaves open the question of why the Discrimination Group learned less than the other Groups about the auditory cue. Possible explanations for this reduced learning will be discussed in Chapter 6.

CHAPTER 4

EXPERIMENT 2

Experiment 1 demonstrated blocking of the acquisition of auditory control in the pigeon by training a prior discrimination based on visual cues. The remaining three experiments each attempted to block the acquisition of visual control in the pigeon by training a prior discrimination based on auditory cues. The first of those experiments is reported in this chapter.

DESIGN

Experiment 2 was designed to determine whether the stimulus control acquired by the orientation of a grid projected on the key could be reduced by prior training to discriminate between tone and noise. The design of the experiment is shown in Fig. 6. Two groups of pigeons were each given two phases of discrimination training. They were taught to discriminate between positive and negative trials on the basis of an auditory cue alone (tone vs. noise), or the auditory cue in addition to a superimposed visual cue (0° vs. 45° orientation of a grid projected on the key).

The Discrimination Group first learned to discriminate on the basis of a single cue, after which a second correlated cue was added. The Control Group initially had both cues available, after which one of the cues was removed. In order to measure the degree of stimulus control which had been established, tests for stimulus control were given to each

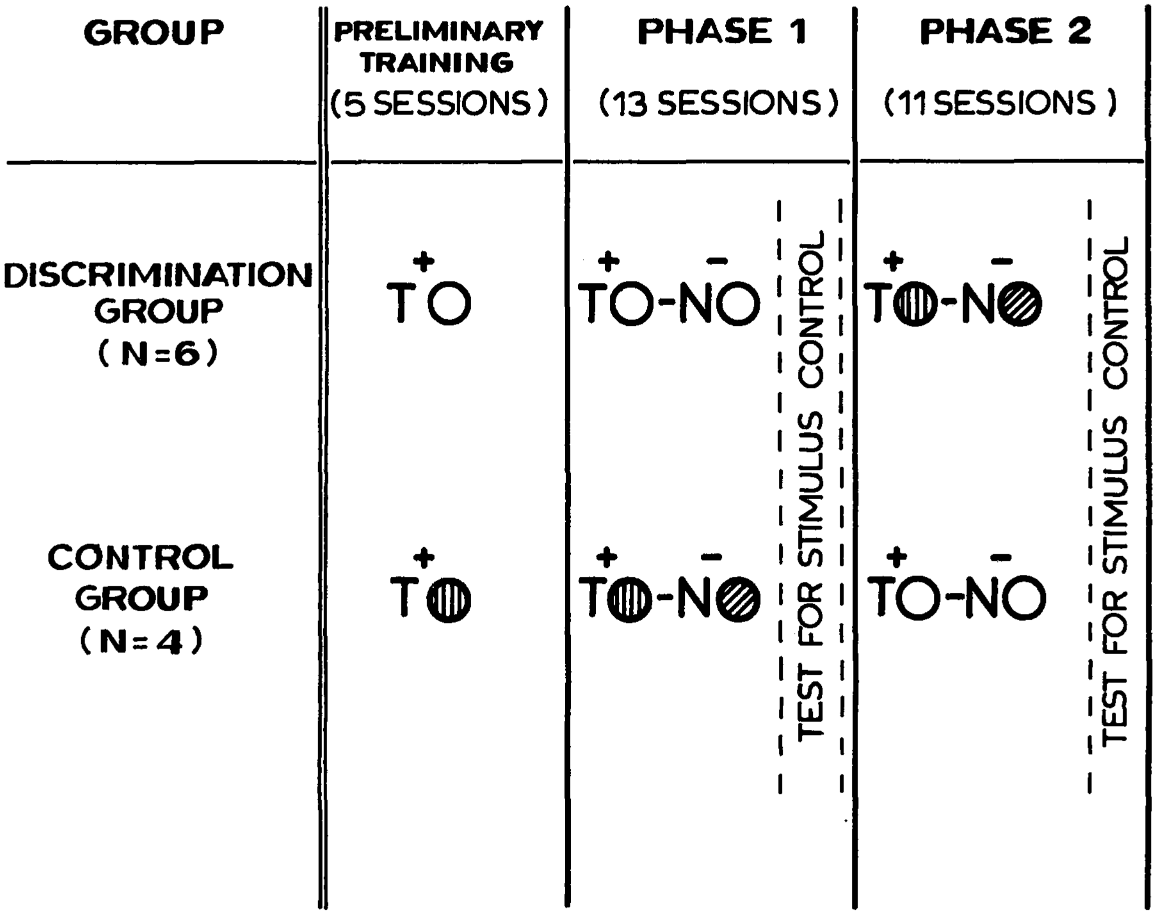

Fig. 6. Stimuli present during positive (+) and negative (-) trials in Experiment 2. The key was lit on each trial: it could be patterned with a 0° or a 45° grid, or could be lit without any pattern. The auditory condition during a trial could be tone (T), noise (N), or silence (used only on tests). Between trials the silence condition prevailed and the key remained unlit.

group near the end of Phase 1 and after Phase 2. In this design, blocking of control by the visual cue in the Discrimination Group would be indicated if that group showed less control by grid orientation after Phase 2 than the Control Group showed after Phase 1.

In order to prevent the Discrimination Group from receiving specific irrelevance training regarding grid orientation during Phase 1, or even nonprediction training with any grid orientation present but not predicting reinforcement, trials were indicated during that phase by the lighting of the key with no pattern.

The blocking comparison does not require the second phase of learning and the second test for stimulus control in the Control Group. These were given in order to examine what will be called *erasing*. Does continued training on a tone-noise discrimination cause a loss of visual control in the Control Group? Experiments by Johnson (1966) and Jenkins (unpublished data) suggest the possibility of such an effect. It was thought that a comparison of the degree of visual control in the two groups after Phase 2 would have implications for our interpretation of the "blocking" phenomenon. If visual control were weaker in the Discrimination Group than in the Control Group after both phases, the probability of certain explanations of lower visual control in the Discrimination Group would be reduced. For example, the possible explanation that an animal can hold only one strong discrimination at a time could be discounted. Explanations which made reference to specific irrelevance training, or to the existence of an interaction on the test, would seem less likely. If, on the other hand, there was no difference between the groups in degree of visual control, we might become suspicious of any account of the blocking effect which depends upon the order of training.

METHOD

Subjects and apparatus

Ten male white King pigeons maintained at 75-85% of their free feeding weight served as subjects. They were 5-6 years old and without experimental history.

A single experimental chamber was used. It was an 11" by 11" by 15" high metal box housed inside a sound attenuating wooden box. A dim houselight extended along the top of one wall of the chamber. In the center of that wall, 9" from the floor, was a 1" diameter circular hole through which a clear glass key could be pecked. Behind the key was a translucent piece of plastic illuminated by a beam of light from outside the chamber. Patterned disks could be swung into position between the glass key and the translucent plastic. In this experiment the patterns used were vertical (0°) and 45° grid orientations. The grids consisted of 21 thin black lines placed parallel to and equidistant from each other across the 1" circular mount. It was also possible to turn the key light on with no pattern present (white key).

Mounted on one side of the chamber was a 4" speaker through which a 1000 cps tone or a white noise could be presented. The tone and noise were generated and measured as described for Experiment 1. Tone and noise intensities were each set at 80 db for this experiment. Sound levels were monitored daily and adjusted as necessary. A ventilation fan which remained on throughout each session generated a background noise of 62 db (the "silence" condition).

Stimuli were presented and responses recorded automatically by means of relay and timer circuits; this apparatus was outside the small room in which the experimental chamber was located. A continuous record of all sessions was made by an Esterline-Angus operations recorder.

Procedure

The experiment used a discriminated trial procedure similar to that used in Experiment 1. Between trials the houselight remained on but the key was unlit; neither tone nor noise was present. Responses occurring between trials were never reinforced. The apparatus was arranged so that responses occurring within .9 sec after the end of the previous trial were not counted as intertrial responses. In this experiment, intertrial responses prevented the onset of another trial during the next 60 sec. This contingency was in effect throughout all training.

Trials were indicated by the lighting of the key. Additional stimuli indicated whether the trial was positive or negative. Trials were terminated when 7 seconds had elapsed or when 4 responses (a response unit) had been made. Reinforcement was 4 sec access to grain in this experiment. Trials were presented on the average every 30 sec, trial starting times being equally often 15, 22.5, 30, 37.5, and 45 sec apart.

Two groups of pigeons were used. The Discrimination Group (6 pigeons) was run Sun, Tue, and Thu of each week, and the Control Group (4 pigeons) was run Mon, Wed, and Fri. The stimuli presented to each group are shown in Fig. 6.

Preliminary training The procedures used in preliminary training (sessions 1 through 5) were similar to those described for Experiment 1, except that (a) only 40 positive trials were presented in each session of pretraining, and (b) the response unit was increased from 1 to 4 in 40 positive trials given directly following training to peck the key in session 1.

Phase 1 Starting with the sixth session 80 trials were presented per session. Half of these were positive and half were negative; they were presented in a mixed order such that an equal number of positive and negative trials were presented in each half of each session. Three different orders were used for each group, and orders were changed daily for each pigeon.

After 10 discrimination sessions, 4 of the 6 pigeons in the Discrimination Group and all 4 pigeons in the Control Group were given tests for stimulus control. The tests came on a normal running day; the pigeons not tested were not run on that day. In the following two sessions all pigeons were returned to their Phase 1 discrimination in order to enable analysis of the effects of the test and to more closely equate the pigeons before moving them to Phase 2.

Phase 2 Starting with the next (19th) session, both groups were presented with their Phase 2 stimuli for 10 sessions. In the following session all pigeons were given tests for stimulus control. In a final session they were returned to their Phase 2 discrimination. Special procedures used in moving some pigeons to Phase 2 are described later (p.79).

Tests for stimulus control Three auditory stimuli (tone, noise and silence) and three visual stimuli (0° grid, 45° grid, and no grid) were used on trials during the tests, in all nine combinations. Twenty mixed sequences of the nine stimuli were used, giving a total of 180 trials. Trials were programmed and terminated as they had been previously, except that reinforcement never occurred.

Tests were completed in a single session which lasted longer than training sessions. The nine stimuli were presented in a mixed sequence; 10 different mixed sequences were presented successively for the first 90 trials of the test for stimulus control, and then this whole sequence was repeated to give a total of 180 trials. Each bird was presented with one of four different such orders.

RESULTS AND DISCUSSION

Intertrial responding The 10 pigeons made a total of only 62 intertrial responses in 27 training sessions and two tests. This averages to less than one every four sessions for individual pigeons.

Discrimination learning Discrimination performance during Phase 1 and Phase 2 is shown in Fig. 7. The pigeons had been given only positive trials during preliminary training; they continued to respond to almost all positive trials during the discrimination phases. Improvement in the discrimination is therefore indicated by a reduction in responding to negative trials.

In Phase 1, the group with both cues available (Discrimination Group) learned faster than the group with only the auditory cue. On the second day of discrimination training there was a distinctive drop in S- response units for each of the 4 Control Group pigeons, whereas 5 of the 6 pigeons in the Discrimination Group completed all 40 S- trials. At the end of Phase 1 all pigeons appeared to have reached an asymptote of S- response units. This asymptote ranged from 1 to 10 response units in the Discrimination Group, and from 0 to 1 response units in the Control Group. The presence of the visual cue in addition to the auditory cue enabled more rapid learning of the discrimination and a lower asymptote of S- responses in Phase 1.

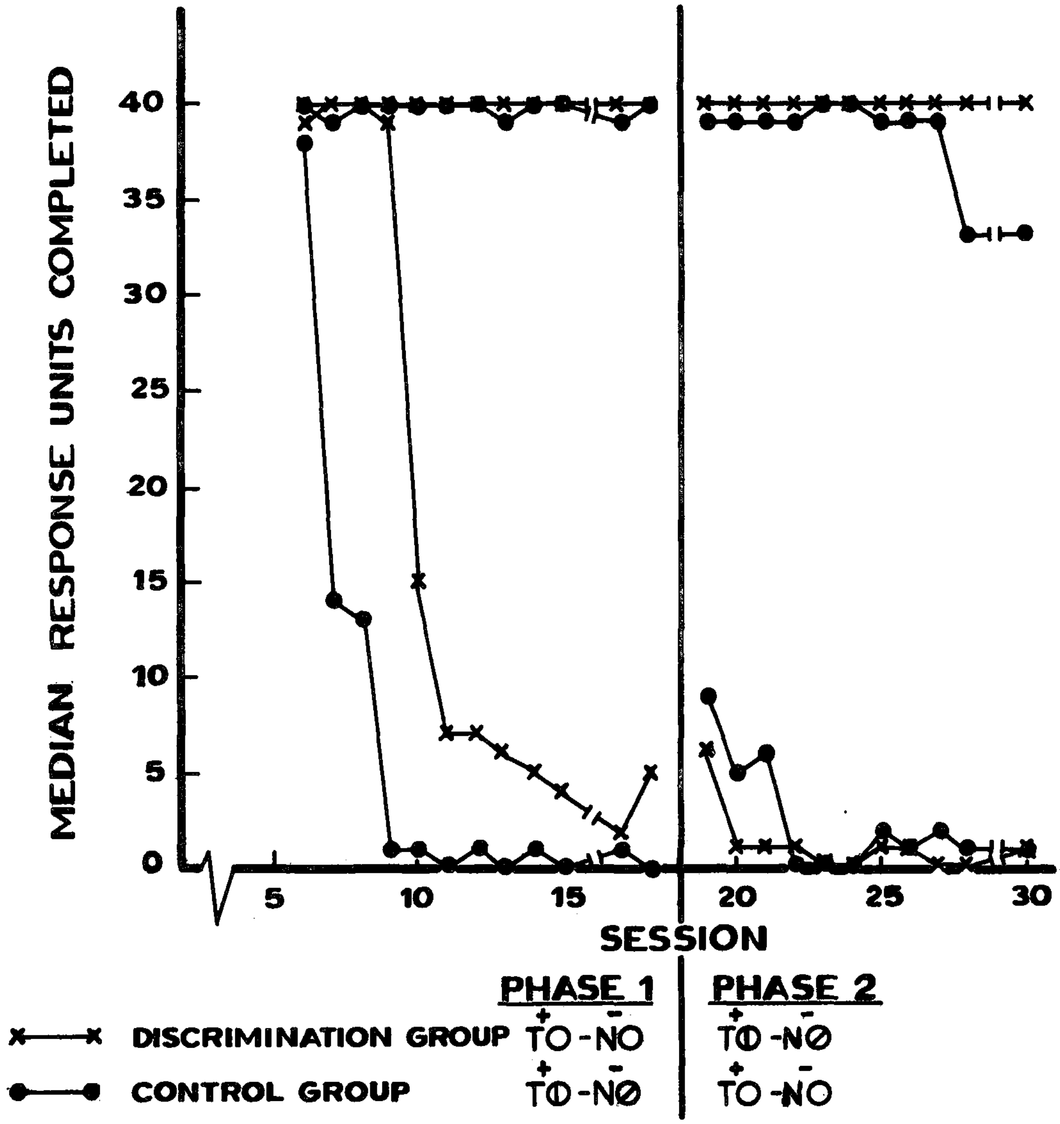

Fig. 7. Median number of response units completed on positive trials (upper lines) and negative trials (lower lines) in Experiment 2. Tests for stimulus control were given in sessions 16 and 29.

The Discrimination Group received an additional (visual) cue in Phase 2. For each of the 6 pigeons, the addition of this cue caused their S- responses to drop to a new asymptote. For the Control Group, the visual cue was removed. This caused a decrement in performance. The number of response units on negative trials increased, and then fell again to an asymptote. This increased S- responding occurred in all 4 pigeons, but was a large effect in only one (#46), who made over 20 S- response units on each of his first three days in Phase 2.

Two other results should be mentioned here. First, the tests for stimulus control did not appear to disrupt discrimination performance on the day following the test (see Fig. 7). Second, there was a great deal of difficulty in getting some pigeons to respond at the beginning of Phase 2. This occurred in both groups, and was due to the changed key pattern. When exposed to the new pattern, some of the pigeons failed to respond. To overcome this, all pigeons were given special training to respond to their Phase 2 S+; this training was given immediately prior to their first session on their Phase 2 discrimination. It was necessary in some cases to "shape" the pigeons, almost as if they had no experimental experience whatever.* There did not seem to be any difference between the two groups with respect to ease of transition. Despite the difficulty of transition for some pigeons, performance on the Phase 2 discrimination did not seem to be disrupted once the transition was made (e.g. see Fig. 7, Discrimination Group).

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* For example, #42 required 35 "shaping" trials to get him pecking at the beginning of Phase 2; he required 37 trials in initial shaping. Bird #50 required 25 shaping trials at the beginning of Phase 2 compared to 6 initially; #41 required 20 shaping trials compared to 11 initially; #46 required 40 compared to 48 initially; #49 required 14 compared to 30 initially. On the other hand, some pigeons moved very easily from Phase 1 to Phase 2.

Test results

We will now consider the results of the tests for stimulus control, using the indices parallel to those described for Experiment 1 (p. 54). The multiplicative indices of visual control for each subject are shown in Table 3. This table illustrates some of the comparisons made below.

Blocking Blocking of control by the visual cue due to prior training on the auditory cue would be shown if the Discrimination Group showed less control by the visual cue after Phase 2 than the Control Group showed after Phase 1. Table 3 shows that this was in fact the case, although there is overlap between the groups. The effect is in the right direction by all indices of visual control. It is significant by the overall additive index ($P<.02$), and barely misses statistical significance by the overall multiplicative index ($.05<P<.07$). It is significant by the results of the trial analysis ($P<.02$).

It is therefore likely that some blocking did occur. However, blocking is certainly not complete, since the Discrimination Group showed some visual control.

Erasing Erasing of control by the visual cue due to continued training on the auditory cue alone would be shown if the Control Group showed less control by the visual cue after Phase 2 then after Phase 1. Table 3 shows that 3 of the 4 pigeons did show some decrease in control, while the fourth showed an increase. Use of the additive index shows an identical pattern, while the trial analysis shows even less of a loss in control. There may have been some erasing, but it was certainly not a strong effect.

TABLE 3

TEST RESULTS FOR EXPERIMENT 2: INDICES OF VISUAL CONTROL

GROUP AND SUBJECT		INDEX OF CONTROL: ⦶/(⦶+⊘)	
Discrimination Group, Second Test	#9	.65	Mean = .55
	#21	.58	
	#35	.54	
	#42	.51	
	#47	.55	
	#50	.51	
Control Group, First Test	#41	.71	Mean = .70
	#46	.94	
	#49	.60	
	#51	.56	
Control Group, Second Test	#41	.56	Mean = .66
	#46	.86	
	#49	.71	
	#51	.53	

Comparison between groups at the end of Phase 2 We may make a direct comparison between blocking and erasing by asking how much control by the visual cue is left in each group at the end of Phase 2. The indices described above all show that, on the average, the Control Group had stronger visual control than the Discrimination Group. By none of the indices is this difference statistically significant.

SUMMARY OF EXPERIMENT 2

Two groups of pigeons were used in an experiment which sought to examine the blocking and "erasing" of control by a visual cue (the orientation of a grid projected on the key) as a result of training to discriminate on the basis of an auditory cue (tone vs. noise). The Discrimination Group (N=6) was taught to discriminate between positive and negative trials on the basis of the auditory cue, after which the visual cue was superimposed. The Control Group (N=4) initially had both cues available, and then the visual cue was removed. Tests for stimulus control showed that (1) although the animals in the Discrimination Group did learn something about the superimposed visual cue, they showed less control by the visual stimulus after training on both stimuli than did the Control Group, (2) the Control Group showed only a small degree of loss in visual control after training with the visual cue removed, and (3) the final degree of visual control was lower in the Discrimination Group than in the Control Group, but this difference was not significant.

CONCLUSIONS

Experiment 2 suggests that blocking is possible with the stimuli used, but does not demonstrate it conclusively. Diminished visual control in the Discrimination Group probably does occur with these stimuli: although the decreased control is of marginal statistical significance by some indices of control, the small number of subjects makes this not surprising. It is not likely that this decrease in control was due to an interaction on the test for stimulus control, since a significant difference was shown even by the trial analysis, which we would expect to be least influenced by such an interaction. Nor was the reduced control in the Discrimination Group caused by specific irrelevance training or nonprediction training, since the design of the experiment prevented this sort of training. However, the possibility remains that the reduced control in the Discrimination Group was due to some other aspect of its Phase 1 training. Experiment 1 showed that it could have been due to partial reinforcement, and we cannot rule out the possibility that _any_ Phase 1 training (or perhaps even the passage of time) might cause a reduction in control subsequently acquired by the visual cue. Experiment 2, then, can only be considered suggestive. The reduced control in the Discrimination Group leaves open the possibility that blocking occurs with these stimuli, but this effect is not conclusively demonstrated.

Although some "erasing" may have occurred in this experiment, it was not a strong effect. The possibility of erasing is not considered again in the experiments which follow, since additional control groups would be required to locate precisely its implications for blocking. For example, blocking is defined as diminished control due to discrimination training, not simply the passage of time, and one would similarly want to know whether the loss of control when SST follows DST is due merely to the passage of time or to some specific aspect of the training received in

Phase 2. Evaluation of these alternatives remains a task for further experiments.

CHAPTER 5

EXPERIMENTS 3 and 4

Like Experiment 2, Experiments 3 and 4 dealt with the possibility of reducing control by a visual stimulus as a result of prior training to discriminate between tone and noise. They were designed to explore the possibility that such reduced control could be obtained more rapidly than in Experiment 1 and 2 by using shorter training periods. The training periods were shortened by ending each phase of training when the majority of Ss reached a low level of responding on negative trials, rather than giving several days training after low levels were reached as was done in the first two experiments. In addition, the visual cues were made more distinctively different on positive and negative trials to increase the speed of discrimination learning. It was felt that this change might also increase the strength of the blocking effect. Part of the reason for the marginal strength of that effect in Experiment 2 may have been that even the Ss in the Control Group did not show very strong control by the visual cue. This meant that the baseline against which to observe reduced control in the Discrimination Group was not ideal. If the visual control in the Control Group could be increased by increasing the distinctiveness of the visual cue, this might result in a greater difference in control between the two groups, and a stronger blocking effect.

Since the experiments were designed as exploratory experiments, only a small number of subjects was used in each experiment. The experiments were not successful in locating strong blocking effect, and they will be described only briefly. The experiments are reported here, however, because some knowledge of the strength of the blocking effect, and the limitations of the conditions under which it may be found, is felt to be important.

DESIGN OF EXPERIMENT 3

The design of Experiment 3 is shown in Fig. 8. The Discrimination Group was trained in Phase 1 on a tone-noise discrimination in which trials were indicated by the lighting of a white key; in Phase 2 a visual cue was available as well as the auditory cue. The Control Group received only training with both cues available. As in experiment 2, tests for stimulus control were given to determine whether the training given the Discrimination Group in Phase 1 diminished the amount of control gained by grid orientation.

One additional feature of the design involved the stimuli present during pretraining. In each group one pigeon was pretrained with the visual stimulus it was to receive in Phase 1 and the remaining three pigeons were given varied pretraining, in which the vertical grid and white key were each presented on half the trials, in a mixed order. This aspect of the design was intended to test the possibility that varied pretraining would diminish a problem found in Experiment 2. The problem was that animals initially trained to peck a grid hesitated to peck a white key, and vice versa. This caused a difficulty in the transition

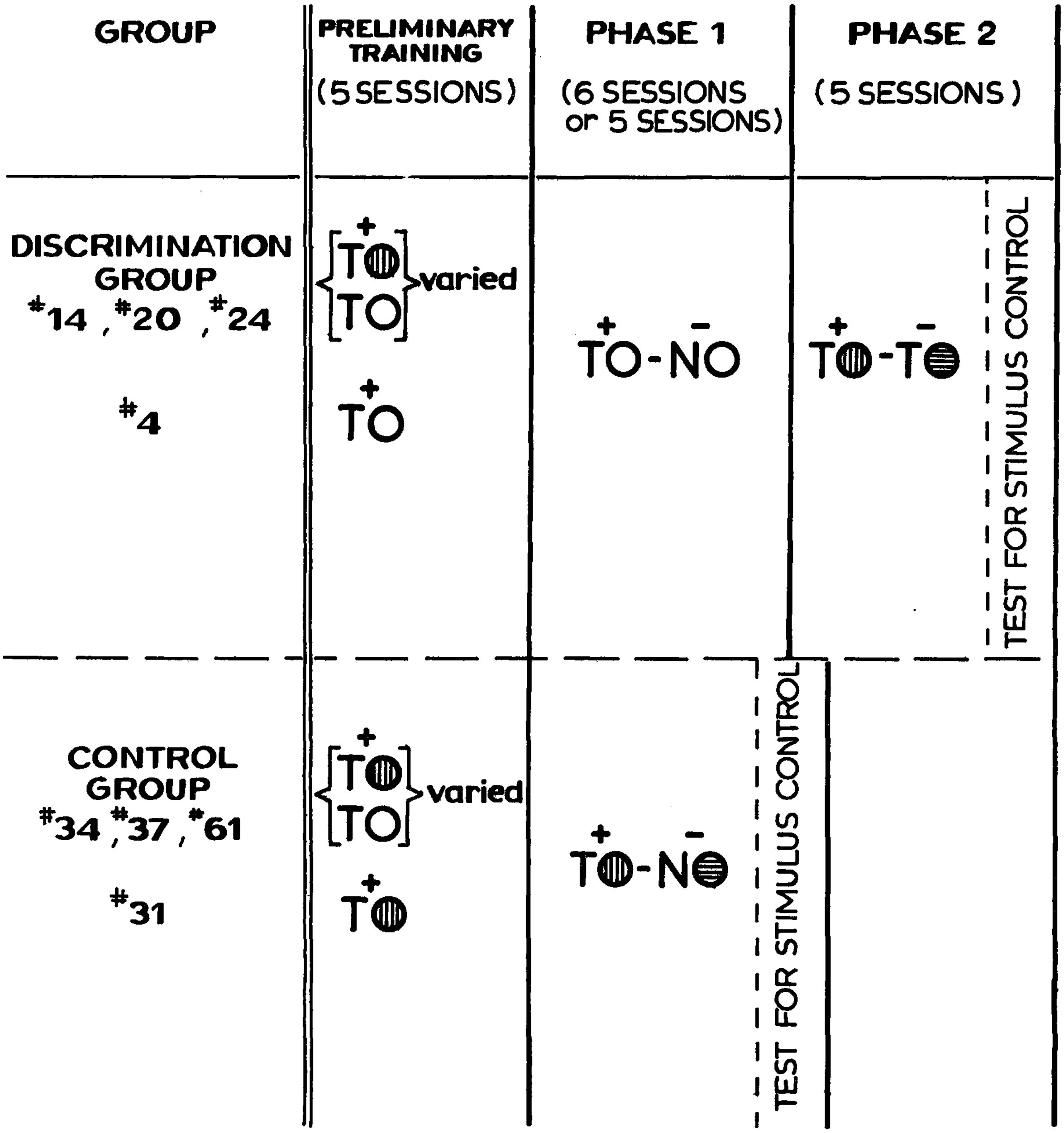

Fig. 8. Stimuli present during positive (+) and negative (-) trials in Experiment 3. The key was lit on each trial; it could be patterned with a 0° or a 90° grid, or could be lit without any pattern. The auditory condition during a trial could be tone (T), noise (N), or silence (used only on tests). Between trials the silence condition prevailed and the key remained unlit.

from Phase 1 to Phase 2, (p. 79 above), and affected the distribution of responses on the test for stimulus control. Since the problem is not of interest in what follows, however, it will not be dealt with. It did not occur as strongly in Experiment 3 as in Experiment 2, and it does not disturb any of the conclusions drawn in this thesis.

DESIGN OF EXPERIMENT 4

The visual stimuli used in Experiment 4 were colors of the key light. The experiment asked whether it was possible to block the acquisition of control by stimuli which are "strong" in the sense that animals show stimulus control following even non-differential training on such stimuli (Guttman & Kalish, 1956; see Baron, 1965). An experiment by Reynolds (1961) suggested that this might be possible. Reynolds trained two pigeons to discriminate in a situation where either or both of two visual cues could be utilized. A later test of stimulus control showed that one of the pigeons was strongly controlled by the first cue but not by the second, while the other was strongly controlled by the second cue but not by the first. On the assumption that which of the two cues the pigeons used could be manipulated by prior training, this result suggests that it might be possible to block control even by a visual cue which is usually considered "strong" for the pigeon.

The design of Experiment 4 is shown in Fig. 9. The design includes control groups intended to allow evaluation of some of the alternative explanations for any diminished control which might be found in the Discrimination Group. The control groups are similar to those used in Experiment 1, and the rationale behind them is described more fully in Chapter 3. They allow evaluation of the possibilities that (a) <u>any</u>

GROUP	PRELIMINARY TRAINING (5 SESSIONS)	PHASE 1 (9 SESSIONS)	PHASE 2 (2 SESSIONS)	
DISCRIMINATION GROUP (N=4)	$\overset{+}{\text{T}}$Ⓦ TⓇ varied	$\overset{+}{\text{T}}$Ⓦ-$\overset{-}{\text{N}}$Ⓦ	$\overset{+}{\text{T}}$Ⓡ-$\overset{-}{\text{N}}$Ⓖ	TEST FOR STIMULUS CONTROL
S+ONLY GROUP (N=2)	$\overset{+}{\text{T}}$Ⓦ TⓇ varied	$\overset{+}{\text{T}}$Ⓦ	$\overset{+}{\text{T}}$Ⓡ-$\overset{-}{\text{N}}$Ⓖ	
PARTIAL GROUP (N=2)	$\overset{+}{\text{T}}$Ⓦ TⓇ varied	$\overset{+}{\text{T}}$Ⓦ-$\overset{-}{\text{T}}$Ⓦ	$\overset{+}{\text{T}}$Ⓡ-$\overset{-}{\text{N}}$Ⓖ	

Fig. 9. Stimuli present during positive (+) and negative (-) trials in Experiment 4. The key was lit on each trial; it could be illuminated with white (W), red (R), or green (G) light. The auditory condition during a trial could be tone (T), noise (N) or silence (used only on tests). Between trials the silence condition prevailed and the key remained unlit.

Phase 1 training reduces visual control; (b) reduced visual control in the Discrimination Group is contributed to by partial reinforcement; and (c) reduced visual control in the Discrimination Group is contributed to by nonprediction training with a white key present but not predicting reinforcement.

METHOD

Subjects and Apparatus

Subjects Sixteen white King pigeons maintained at 75-85% of their free feeding weight served as subjects. They were 5-6 years old and without experimental history.

Apparatus The apparatus was similar to that described for Experiment 1. Three experimental chambers were located in a small room. Chamber 3 was the chamber which had been used in Experiment 2; it was now used in Experiment 3. Chamber 2 was a standard Lehigh Valley pigeon chamber; it was used in Experiment 4. Chamber 1 was used in another experiment which will not be reported here. Each chamber had a key which closed an electrical contact when pecked and so allowed recording of the pigeon's pecks, a loudspeaker, and a grain hopper that could be raised into position for reinforcement. Since auditory stimuli were used in each of the chambers, attempts were made to decrease sound transmission from box to box by separating the boxes physically and by supporting them with sound insulating material. The control apparatus was the same as that used for Experiment 1.

Stimuli As in the previous experiments, three auditory and three visual stimuli were available in each chamber. Auditory stimuli were tone, noise, and silence. An 80 db tone and 80 db white noise were generated and measured as described for Experiment 1; sound levels were monitored daily and adjusted as necessary. In each chamber a ventilating fan remained on throughout each session, generating a background noise of 63 db in chamber 3 and 62 db in chamber 2 (the "silence" condition).

The visual stimuli used in chamber 3 were similar to those used in Experiment 2, except that 0° and 90° orientations of the grid were used. Position and pattern of the grids was varied every second day so that neither specific pattern used nor apparatus position could successfully be used as cues.

The key in chamber 2 could be lit with white, red, or green light. The white light was obtained by lighting the white-filtered bulb supplied by the manufacturer. The red and green lights were obtained by lighting the red- or green-filtered bulbs supplied and in addition partially lighting the white light. The resulting red and green key colors were more saturated than those used in Experiment 1, where the white light was fully lit and the red or green lights only partially lit.

Procedure

Both experiments used a trial procedure very similar to that used in Experiment 1. Trials were terminated at the completion of a response unit (four responses) or after 7" had elapsed. The time between trial onsets averaged 50"; it was frequently only 40", and occasionally as long as 85". Most sessions were slightly less than 70 minutes long. As in Experiment 1, responses occurring between trials had no effect. Reinforcement initially consisted of 4" access to grain. However, some animals continued to gain weight, so after 10 days the tray operate time was reduced to 3.6".

Each animal was run daily at approximately the same time. In the first session the animals were trained to peck the key. In the second to fifth sessions, they received 60 positive trials per session. Their response unit was increased from 1 to 4 during the second and third sessions. Some animals were shaped and pretrained with a single trial stimulus; for others 2 different trial stimuli were used in a mixed order.

Following pretraining, animals were put on various schedules as shown in Figs. 8 and 9. Where discriminations are indicated in these Figs., the subjects received 40 positive and 40 negative trials daily. The two animals in the S+ Only Group of Experiment 3 were the only animals not receiving 80 trials after the fifth day. They received 60 positive trials daily.

Tests for stimulus control consisted of two consecutive sessions of 81 nonreinforced trials. In each session there were nine sequences of trials; each sequence contained nine different trial stimuli in a mixed order. The nine stimuli were tone, noise, and silence with each of the three visual stimuli shown in Fig. 8 or 9.

The total length of training was 18 days in each experiment. The number of days spent on a given discrimination is indicated in Figs. 8 and 9.

RESULTS AND DISCUSSION

Intertrial responding

Apparatus problems prevented precise recording of ITRs in chamber 2. In chamber 3, the number of ITRs for individual birds during the last day of pretraining ranged from 7 to 112. The median number of ITRs per day for the remainder of the experiment was also calculated for each bird in chamber 3; that number ranged from 17 to 93.

Learning results

The learning curve for Experiment 3 is shown in Fig. 10. The animals with two cues learned to discriminate faster than those with only one, as in Experiment 2. One unexpected result was the increase in S- responding for the Discrimination Group at the beginning of Phase 2. This did not occur in Experiments 1 or 2, and might possibly have been the result of the varied pretraining used, although it occurred even in the subject who had received constant pretraining. Another possibility is that the newly presented grid produced "disinhibition" of the response. A disinhibiting stimulus is known to be less effective when a long period of training precedes its presentation (Brimer, 1963), and possibly this explains the failure of a similar increase in responding to occur following the introduction of a grid in Experiment 2, where Phase 1 was considerably longer.

The learning curve for Experiment 4 is shown in Fig. 11. It shows that in Experiment 4 there was no rise in S- responding when the Discrimination Group moved to Phase 2. It also shows that the Control Group animals made a fairly high number of S- response units on the first day of Phase 2. This number dropped sharply on the second day, showing that the visual stimuli used were indeed easier to discriminate than the visual cues used in previous experiments.

Blocking results

The blocking results may be described simply: there was little evidence for blocking in either experiment.

Summary indices of visual control in each experiment are shown in Table 4. If there were blocking effects, we would expect that in each

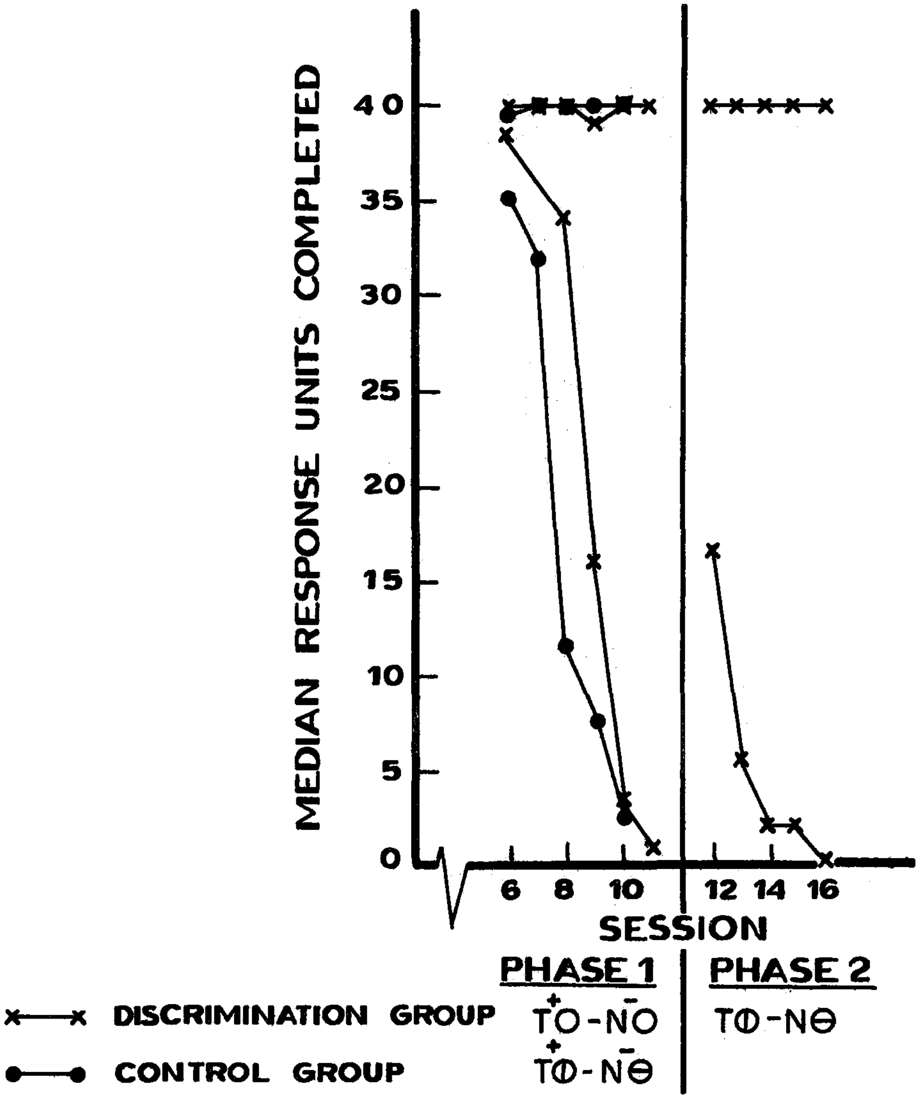

Fig. 10. Median number of response units completed on positive trials (upper lines) and negative trials (lower lines) in Experiment 3.

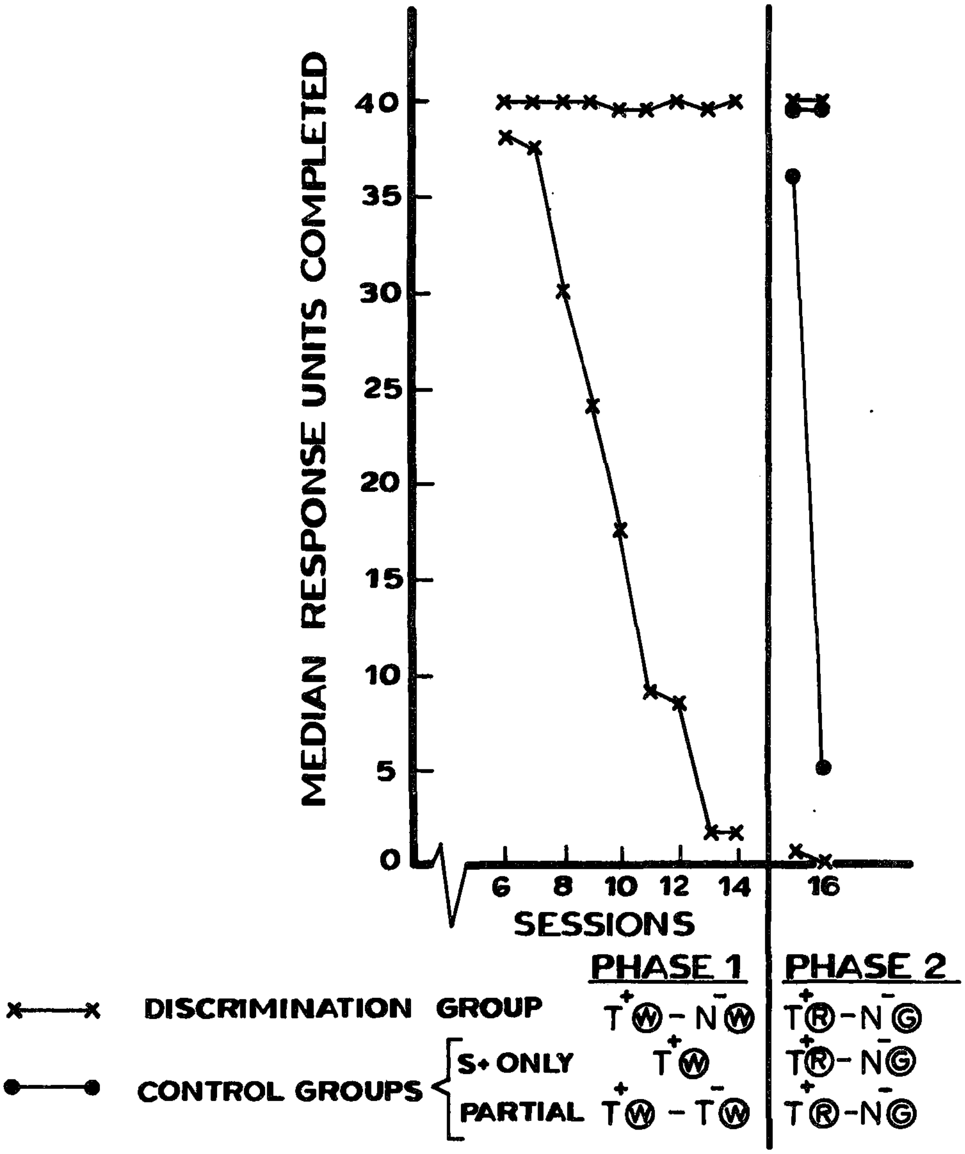

Fig. 11. Median number of response units completed or positive trials (upper lines) and negative trials (lower lines) in Experiment 4. Data for the two control groups are combined.

TABLE 4

TEST RESULTS FOR EXPERIMENTS 3 AND 4: INDICES OF VISUAL CONTROL

EXPERIMENT 3

GROUP AND SUBJECT		INDEX OF CONTROL: ⦶/(⦶+⊖)	
Discrimination Group	#4	.560	Mean = .632
	#14	.647	
	#20	.713	
	#24	.609	
Control Group	#31	.782	Mean = .721
	#34	.511	
	#37	.936	
	#61	.654	

EXPERIMENT 4

GROUP AND SUBJECT		INDEX OF CONTROL: Ⓡ/(Ⓡ+Ⓖ)	
Discrimination Group	#2	.979	Mean = .869
	#7	.856	
	#28	.726	
	#33	.913	
Control Groups	(S+) #16	.913	Mean = .927
	(S+) #36	.958	
	(P) #23	.946	
	(P) #60	.891	

experiment the Discrimination Group would show less visual control than the Control Group. Although the average visual indices of the groups show a difference in the right direction, there was a considerable degree of overlap in each experiment, and the differences did not approach statistical significance. Use of most of the other indices of visual control showed even more overlap. There was no evidence for a strong blocking effect in either experiment.

There is a possible explanation for the failure to find blocking in Experiment 3. In that experiment, the Discrimination Group increased their S- responses at the beginning of Phase 2. If the prevention of nonreinforced responding to the horizontal grid is critical for the blocking of control by grid orientation, the occurrence of these S- responses would diminish the blocking effect. However, the number of such responses made by subjects in the Discrimination Group still remained substantially below the number made by subjects in the Control Group (there was no overlap).

It might also be argued that blocking was not found in Experiments 3 and 4 due to the use of visual stimuli of inappropriate distinctiveness. Possibly the visual stimuli used in Experiment 3 were still not distinctive enough relative to the auditory stimuli. Once again, as in Experiment 2, the degree of visual control in the Control Group after Phase 1 was not great (Table 4). The increased difference in grid orientation used in Experiment 3 raised the distinctiveness of the visual cue only slightly.

However, it would be difficult to argue that the visual stimuli used in Experiment 4 were not distinctive enough, since even the Discrimination Group was strongly controlled by them. If anything, these stimuli were <u>too</u>

distinctive, since even Ss that made very few S- responses in Phase 2 (a total of 8 responses for #2, 4 responses for #28, and 0 responses for #33) showed strong visual control on the test.

SUMMARY OF EXPERIMENTS 3 AND 4

Two experiments each used eight pigeons in an effort to see whether stronger blocking would occur when the strength of the visual cues was increased over that in Experiment 2. In each experiment the Discrimination Group was taught to discriminate on the basis of tone-noise, and then a visual cue was added. In Experiment 2 this visual cue was 0° vs. 90° orientation of a grid projected on the key; in Experiment 3 it was pale red vs. pale green key light. In neither experiment was visual control in the Discrimination Group significantly below visual control in the Control Groups: there was little evidence for blocking.

IMPLICATIONS OF EXPERIMENTS 2, 3, AND 4

Experiments 2, 3, and 4 were each designed to examine whether training on a prior auditory discrimination will block the subsequent acquisition of control by a visual stimulus presented on the key. In each experiment blocking would have resulted in reduced visual control in the Discrimination Group. The experiments did not, however, include controls for certain other factors that might also reduce visual control.

In Experiment 2 the Discrimination Group showed reduced control, although the differences observed there were of marginal statistical significance. Although it could not be concluded that this reduced control was due to blocking, the results did leave open the possibility that blocking occurred. Experiments 3 and 4, on the other hand, showed little if any reduced control in the Discrimination Group, which means that little if any blocking would have occurred. Can any general conclusions be drawn from these data?

One possibility is that, in the pigeon, prior training on an auditory discrimination simply cannot block the acquisition of control by a visual stimulus presented on the key. It may be recalled that Chase (1966) failed to find blocking of visual control by prior auditory training. It is possible that the differences observed in Experiment 2 were due to chance (although it should be recalled that Experiments 3 and 4 each found differences in the same direction) or to other factors that were not controlled for.

A second possibility is that blocking can occur with these stimulus dimensions, but that its demonstration requires a judicious selection of stimulus values, training periods, or other experimental parameters. If blocking the acquisition of visual control by prior auditory discrimination training can occur, Experiments 2, 3, and 4 taken together suggest certain boundary conditions for it. For instance a comparison of Experiments 2 and 3 suggests that the length of Phase 1 training may be important. The stimuli used in Experiment 2 were quite similar to those used in Experiment 3. However, the length of Phase 1 was considerably greater in Experiment 2, and the difference between groups was greater in that experiment. It is possible that blocking will not occur unless the training on the prior discrimination in Phase 1 is continued for several sessions after the subjects have reached a low, asymptotic level of responding to S-.

A comparison of Experiments 2 and 4 suggests another factor likely to affect the amount of blocking: the relation between the distinctiveness of the first and second trained cues. In Experiment 2, where blocking may have occurred, the auditory and visual cues were similar in distinctiveness (the Control Group showed a similar degree of control by each cue after DST). In Experiment 4, however, where the visual cue was much more distinctive than the auditory cue, prior training on the auditory cue did not greatly reduce the control acquired by the visual cue. Increasing the distinctiveness of the visual cue seemed only to decrease blocking.

Let us consider whether increasing the distinctiveness of the _auditory_ cue might increase blocking. One effect of making the auditory cue more distinctive might be to increase the amount of control acquired by the auditory cue during double stimulus training in the Control Group. In addition, making the auditory cue more distinctive might _reduce_ the amount of control acquired by the _visual_ cue during double stimulus training. Experiments by Miles (1965) and by Newman & Baron (1965) suggest that this would occur. They showed that the control acquired by a cue during discrimination training is reduced if an additional cue also predicts reinforcement. Miles (1965) showed that this effect is a graded one depending on the distinctiveness of the second, added cue. If, as these experiments suggest, making the auditory cue more distinctive would reduce visual control in the Control Group, then blocking would be difficult to demonstrate simply because there is not much control to be blocked. These considerations, along with the results of Experiment 4, suggest that the relative distinctiveness of the auditory and visual cues may be an important factor in the blocking of visual control by prior auditory discrimination training.

Experiments 2, 3, and 4, then, do not give conclusive evidence on whether or not prior discrimination training based on an auditory cue can block the subsequent acquisition of control by a visual cue. However, taken as a whole they do suggest two parameters which may affect the amount of blocking found. The first of these is the length of the Phase 1 training given to the Discrimination Group; the second is the relative distinctiveness of the two cues that are used.

CHAPTER 6

TWO EXPLANATIONS OF BLOCKING, AND AN ALTERNATIVE DESIGN

The results of Experiment 1 showed that in at least one situation blocking does occur. The Discrimination Group in Experiment 1 learned less about the added auditory cue than the other groups, and this lower learning seemed to be a result of learning to discriminate on the basis of the visual cue in Phase 1. This final chapter will consider some possible explanations of the finding of blocking. The discussion will center around two alternative explanations of blocking, one based on a two-stage theory of learning and one more in line with traditional theories of learning. Although the experiments reported here were not designed to directly test these theories, each of the theories does predict certain relationships in the data in addition to blocking, and these relationships will be examined. Finally, an alternative experimental design which has been used to test one of these theories will be discussed.

Explanation based on a two-stage theory of learning

This first explanation of blocking may be stated roughly as follows. During Phase 1 the Discrimination Group learns both to attend to the first stimulus dimension and to respond correctly to the stimulus values on that dimension. During Phase 2 it continues to attend to the first stimulus dimension and therefore learns less about the second stimulus dimension. In Experiment 1, the Discrimination Group would be said to learn less about tone-noise during Phase 2 because it was attending to the color of the key.

There are many reasons to be dissatisfied with a "theory" as vaguely formulated as this. As was pointed out in Chapter 1, precise predictions will depend on the exact relation between the first-stage response ("attention") and the second stage response (pecking), the stimuli that control these responses, the relative speed of acquisition of these responses, the forms of feedback which increase or decrease the probability of these responses, and many other factors. Although no attempt will be made here to develop a satisfactory two-stage theory of learning, it does seem possible to outline some of the assumptions such a theory would have to make in order to explain the blocking found in Experiment 1. (a) Discrimination training of the sort given to the Discrimination Group in Experiment 1 would have to produce an increase in the strength of the first-stage response that is referred to by the phrase "attending to color". (b) The stimuli controlling the first-stage response would have to be somewhat more general than those controlling the second-stage response, in order to have the pigeons "attending to color" throughout Phase 2. As Lawrence (1963) has pointed out, the explanatory power of a two-stage theory is lost if the stimuli controlling the two responses are identical. One might assume that the first-stage response is controlled by general aspects of the experimental situation, while the second-stage response is controlled by the specific trial stimuli. (c) The first-stage response would have to be one that modulates the effectiveness with which different stimulus variables can acquire control over a second-stage response. That is, the response "attend to color" would be one that facilitates learning about color. (d) Increased "attention" to one stimulus variable must lead to decreased "attention" to at least some other stimulus variables. The response "attend to color", learned by the Discrimination Group in Phase 1 and carried into Phase 2, must decrease the ease with which auditory control over the pecking response can be acquired.

A model of learning that makes these assumptions has been described by Sutherland (1964a). Although assumption (b) above is not stated explicitly by Sutherland, it seems to be implied. In addition, Sutherland's model assumes that the strength of the second-stage response reaches asymptote more rapidly than the strength of the first stage response. This assumption is made in order to explain the overlearning reversal effect, (Mackintosh, 1965b), but it has interesting implications for the present experiments as well. In particular, one might predict from Sutherland's (1964a) model that overtraining given in Phase 1 would increase the strength of the "attention" response and thereby increase the blocking effect. A comparison of Experiments 2 and 3 seems to support this prediction: a larger difference between groups was found in Experiment 2, where Phase 1 training was continued beyond the point of asymptotic responding to positive and negative trials. Although this finding is suggestive, it certainly does not prove that the two-stage theory of learning proposed by Sutherland (1964a) is the correct explanation of these data. The alternative explanation for blocking to be given below also predicts stronger blocking in Experiment 2 than in Experiment 3, but for a different reason.

The model proposed by Sutherland (1964a) has certain other implications for the data gathered in these four experiments. These implications have to do with the relation between the amount of control shown by the auditory and the visual cues. Sutherland's model predicts that "the more an individual S learns about one cue, the less it should learn about the other" (Sutherland & Holgate, 1966, p. 199). There are several places in these four experiments where such a relationship fails to hold.

1. In Phase 1 of Experiment 2, the Discrimination Group was given training with only the auditory cue predicting reinforcement, while the Control Group was given an equivalent amount of training with both the auditory and the visual cues predicting reinforcement. As a result of this training the Control Group learned about the visual cue while the Discrimination Group did not. However, this increased learning about the visual cue in the Control Group was not accompanied by decreased learning about the concurrent auditory cue. Comparison of auditory indices of control on the test for stimulus control given after Phase 1 shows not less, but slightly more auditory control in the Control Group. The average indices of auditory control were .82 in the Discrimination Group and .91 in the Control Group; individual data are given in the appendix.

2. In Experiment 1, pigeons in the S+ Only Group showed higher indices of auditory control than pigeons in the other groups. However, this higher auditory control was not accompanied by lower visual control (Fig. 4).

3. Sutherland's model predicts that, within groups, any pigeon learning more about one cue is likely to learn less about another. This means that there should be a negative correlation between auditory and visual indices of control within the various experimental groups reported here. The Spearman rank correlation coefficient between overall multiplicative indices of auditory and visual control for each group reported in this thesis is shown in Table 5. The correlation is in the correct direction in only 5 of

TABLE 5

CORRELATIONS BETWEEN AUDITORY AND VISUAL CONTROL[*]

EXPERIMENT	GROUP	N	MEAN AUDITORY INDEX	MEAN VISUAL INDEX	r_s
Experiment 1	Discrimination	5	.578	.956	-.10
Experiment 1	Not Run	6	.752	.846	+.03
Experiment 1	S+ Only	6	.904	.822	-.03
Experiment 1	Partial	6	.719	.888	-.49
Experiment 2	Discrimination (Second test)	6	.98	.55	-.39
Experiment 2	Control (First test)	4	.91	.70	+.20
Experiment 2	Control (Second test)	4	.94	.66	+.40
Experiment 3	Discrimination	4	.923	.632	-.40
Experiment 3	Control	4	.611	.721	+.40
Experiment 4	Discrimination	4	.876	.869	+.40
Experiment 4	Control	4	.613	.927	+.40

[*] Overall multiplicative indices of auditory and visual control were used. N is the number of subjects in the group. The symbol r_s refers to Spearman rank correlation coefficient.

11 groups, and is large in only two of those groups. These correlations certainly could not be used as evidence in favor of a two-stage model of learning such as Sutherland's (1964a). However, they are not sufficient reason for rejecting such a model, since factors such as differences in individual learning ability, health, or overall response strength might work to reduce the size of negative correlations (see Sutherland & Holgate, 1966).

Explanation based on a decrease in S- responses

A second possible explanation of blocking is more in line with traditional theories of learning. As described in Chapter 1, there is much evidence that discrimination training between two stimuli varying along some dimension produces increased stimulus control by that dimension over the response. An important element in such discrimination training is the occurrence of nonreinforced responses to the negative stimulus (S- responses), and it is possible that the occurrence of S- responses is at least partially responsible for the observed increase in stimulus control. Such a relation is postulated in a theory described by Hull (1952, p. 69-75). In that theory, S- responses give rise to a "gradient of conditioned inhibition" around S- which reduces responding to S- while leaving S+ responding relatively unaffected. As a result, variations in the stimulus along the S+ - S- dimension produce greater variations in response strength and we observe greater stimulus control over the response.

Whether or not the particular theory described by Hull is correct, there is much evidence consistent with the notion that the occurrence of S- responses is an important factor in the establishment of stimulus control (see Terrace, 1966). If the occurrence of S- responses does increase stimulus control over the response by the stimulus dimension involved, this could explain the blocking effect found in Experiment 1. The Discrimination Group, having learned in Phase 1 not to respond when the key was green, continued to make very few S- responses in Phase 2 - significantly fewer than any other group. This lack of responding in the presence of the negative auditory stimulus (noise) might have been the reason that the Discrimination Group acquired little stimulus control by tone-noise in Phase 2.

The notion that reducing S- responses reduces the amount of stimulus control acquired explains the blocking found in Experiment 1 and can also explain the results of Experiment 2, where fewer Phase 2 S- responses occurred in the Discrimination Group and less control was acquired by the added stimulus in that group. The notion would also predict blocking in Experiments 3 and 4, since in each of these experiments less Phase 2 S- responding occurred in the Discrimination Group than in the Control Group. However, neither of these experiments found significantly lower control by the added cue in the Discrimination Group. In Experiment 4, there was a good deal of stimulus control acquired by the visual cue in the Discrimination Group despite the fact that some animals made almost no S- responses (see page 98).

It was mentioned above that the difference between Experiments 2 and 3 could be accounted for in terms of the S- response explanation of blocking. In Experiment 3, there was an unexpected rise in S- responses at the beginning of Phase 2 in the Discrimination Group. This would be expected to cause the Discrimination Group to acquire some visual control, diminishing the blocking effect in Experiment 3. In this way the smaller difference between groups in Experiment 3 than in Experiment 2 (where S- responses remained low) would be explained. It should be noted, however, that some blocking would still be predicted in Experiment 3, since the number of S- responses occurring in the Discrimination Group during Phase 2 was still less than that occurring in the Control Group; there was no overlap.

The explanation of blocking described here might also predict other relations in these data. One such prediction will be dealt with in some detail, since it reveals some complexities in the S- response explanation. This prediction is one which does not actually follow from the S- response explanation. It is worth considering, however, since it does initially seem to follow from the S- response explanation, and since in at least one article parallel predictions have been made and their rejection has been considered evidence against explanations similar to the S- response explanation (Mackintosh, 1965a, p. 297-298, on "response latencies" and "number of errors").

The prediction might be stated in this way. If Phase 1 training is differentially effective for different Ss in the Discrimination Group, different numbers of S- responses will be made in Phase 2. Since the occurrence of S- responses produces increased stimulus control, a S making more S- responses than some other S should acquire more control by the added cue. This means there should be a positive correlation between the number of S- responses made and the amount of control acquired by the added cue in the Discrimination Group. This prediction is not supported by the data from Experiments 1, 2, 3, and 4. Spearman rank correlation coefficients between S- response units in Phase 2 and overall multiplicative indices of control by the added cue in the Discrimination Group were +.50, -.89, -.80, and -.25. Only in Experiment 1 was the correlation in the predicted direction.

The problem with this prediction lies in the complex relation between S- responses and the acquisition of stimulus control. While a *between-group* manipulation of S- responses may affect the acquisition of stimulus control, *within-group* variations in S- responses reflect differences in the present state of stimulus control as well. Consider again the argument in the preceding paragraph. The predicted correlation depends on the assumption that Phase 1 training is differentially effective for different *S*s in the Discrimination Group. This assumption is certainly warranted; we know that different *S*s learn at different rates. However, if learning is due at least partly to the occurrence of S- responses, the existence of fast and slow learners means that S- responses are differentially effective for different *S*s. Fast learners, by definition, acquire more control per S- response than slow learners. The complication arises since those *S*s making many S- responses in Phase 2 are the *S*s who did not acquire strong control in Phase 1 —— they are the slow learners, who acquire relatively little control per S- response. This makes prediction difficult, since the *S*s who make more S- responses in Phase 2 also acquire less control per S- response; it is not clear whether the net control acquired by such a *S* should be more or less than that acquired by an *S* making fewer S-responses.

These arguments suggest that the lack of a positive within-group correlation between S- responses and amount of control acquired by the added cue need not be embarrassing to the S- response explanation of blocking. They also suggest ways in which the within-group correlations might be improved. For instance, for each animal we might try to create an index that would reflect amount learned about the added stimulus *corrected for* amount learned about the first stimulus. This might improve the correlation since it would adjust for differences in speed of learning. An alternative way in which the raw correlation between Phase 2 S- responses and control by the added cue might be improved is this: the number of S- responses might be corrected to reflect their effectiveness by taking into account the total number of S- responses made and the total amount of control acquired by the first cue. Several methods of "correcting" the amount of control gained by the second cue or the number of S- responses occurring in Phase 2 were tried; none improved the correlations significantly.

Comparison of explanations

The present experiments were not designed to test the explanations for blocking that have been described here. Each of these explanations can explain the blocking observed in Experiment 1, but neither received impressive support from an examination of additional relations in the data. What sort of experiment might be used to test these explanations independently?

First, it is clear that each of the explanations has wide application outside the blocking paradigm, and many experiments not directly related to blocking are relevant to a decision concerning their validity. For instance, any experiment supporting a two-stage theory of learning that makes the assumptions listed on p. 103 above would support the two-stage explanation of blocking. Similarly, any experiments indicating the importance of S- responses in the acquisition of stimulus control would have implications for the S-response explanation. The findings that stimulus control can be acquired _without_ S- responses in a procedure known as "errorless learning" (Terrace,

1966) and that apparently nondiscriminative training can result in stimulus control (Guttman & Kalish, 1956) show that S- responses need not always occur for stimulus control to be acquired, and suggest limitations on the S- response explanation. Alternatively, the fact that the S- response explanation can explain certain results outside the blocking design supports that explanation. For instance, Newman & Baron (1965) trained one group of pigeons to discriminate between a green key with a white vertical line and a green key with no line; another group learned to discriminate between a green key with a white vertical line and a red key with no line. The first group acquired more stimulus control by line orientation. Baron (1965) has explained these results in terms of a "modification of the attending hierarchy" (p. 66). However, it is also possible to explain the results in terms of the different numbers of S- responses made by the two groups. The first group made many more responses in the presence of the negative stimulus, and this could have caused more stimulus control by line orientation to be acquired by that group.

It is possible that evidence concerning the validity of the two explanations described here could be gained in experiments closer to the blocking design. For instance, it would be interesting to know whether blocking can occur during nondiscriminative training, with no negative trials. More generally, it might be possible to manipulate positive and negative trials independently - the negative stimulus from Phase 1 might be carried over to Phase 2, for instance, but not the positive stimulus.

Experiments using a design quite similar to the blocking design have been used as evidence for a two-stage theory of learning. That design is slightly more complex than the blocking design described in Chapter 2, but has many features in common with it. Many of the distinctions emphasized in this thesis can be applied to that design, and we turn now to a discussion of it.

The two-task design

In the two-task design two groups of animals are presented stimuli in the same manner as in the blocking design (Fig. 1), except that the task is changed from Phase 1 to Phase 2. Experiments of this design have been described by Mackintosh (1965a, Exp. 1) and Sutherland & Holgate (1966, Exp. 6). These experiments were similar to each other in design. In each experiment rats were trained to jump in a Lashley Jumping stand. In Phase 1, rats in the Discrimination Group learned a successive brightness discrimination (e.g. jump left when both stimuli white, jump right when both stimuli black), while rats in the Control Group received no training.* In Phase 2, both groups learned a simultaneous discrimination with both brightness and orientation predicting reinforcement (e.g. black horizontal rectangle positive and white vertical rectangle negative on each trial). In order to evaluate what the two groups learned in Phase 2, a subsequent test examined the stimulus control by each cue over the Phase 2 response.**

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*Each of these experiments also used an additional group that will not be considered here. These additional groups received Phase 1 training with brightness predicting reinforcement and orientation varying in a manner uncorrelated with reinforcement. Reference here to the Discrimination Group in either of these experiments refers to the group that received Phase 1 training with brightness predicting reinforcement but no orientation cue present (Group BW of Mackintosh, 1965a, Exp. 1; and Group A of Sutherland & Holgate, 1966, Exp. 6).

**The requirement that the test measure stimulus control over the task 2 response and not the task 1 response is an important one, since the value of the two-task design depends on the lack of transfer between the two tasks (see below). In experiments using a simultaneous and a successive discrimination as the two tasks, it is very difficult to tell whether this requirement is met, since both tasks involve the same response (jump right and jump left). The tasks can only be separated by bringing stimuli into the description. This point is very interesting, since in order to test control by the two cues separately after Phase 2 it is necessary to use stimuli that in some ways more closely resemble Phase 1 stimuli than Phase 2 stimuli (cf. Mackintosh, 1965a, Exp. 1). This makes it difficult to rule out the possibility that interference from the Phase 1 task occurs

Reason for the task-shift. The important difference between these two experiments and the experiments reported above is the shift in task from Phase 1 to Phase 2. Although neither Mackintosh (1965a) nor Sutherland & Holgate (1966) discusses the rationale for this task-shift, their experiments stem from earlier experiments by Lawrence (1949, 1950), who discusses the reasons for the task change at some length. Briefly, different tasks are used in order to rule out the possibility that the effects of Phase 1 training on Phase 2 learning result from the direct transfer of overt instrumental responses. The task-change is introduced in order to meet the following requirement: "the instrumental behavior learned in the first situation must neither facilitate nor hinder the learning of the instrumental responses in the second situation" (Lawrence, 1949, p. 770). For the moment let us assume that this requirement is in fact met in these experiments. What implications does this have for their results?

If the requirement is met, Phase 1 training with the first cue predicting reinforcement cannot contribute directly to an association between the first cue and the Phase 2 response, and the Discrimination Group would be expected to acquire no more control by the first cue in Phase 2 than the Control Group. If the Discrimination Group did acquire more control by the first cue during Phase 2 than the Control Group, this would be evidence for a two-stage theory of learning. It might be argued, for instance, that Ss learned to "attend" to the first cue in Phase 1, facilitating the acquisition of control by that cue over the second, separate task in Phase 2.

What data are important? If it is true that in the two-task design increased control by the first cue in the Discrimination Group demonstrates "attention" just as fully as decreased control by the second cue, then the

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on the test for stimulus control. To simplify the arguments presented below, the possibility of such interference is ignored, and it is assumed that the indices of stimulus control in such experiments do indeed reflect Phase 2 learning.

data from such an experiment can be analyzed differently from the data of the experiments reported here. Sutherland & Holgate, for example, describe as the main result of their experiment the fact that Ss in the Discrimination Group learned "relatively more about the brightness cue during two-cue training" than did Ss in the Control Group (1966, p. 206). Describing the results in this manner does not differentiate between the Discrimination Group learning (a) more about the first cue or (b) less about the second cue as a result of its Phase 1 training; the authors seem to consider either of these results sufficient evidence that a two-stage theory of learning is required.

It seems important to separate these possibilities. The two-stage theory of learning described by Sutherland (1964a) predicts that both (a) and (b) will occur, but it is also possible that only one of them will occur. Prediction of (a) and of (b) depends on different postulates in Sutherland's (1964a) theory, and as was pointed out in Chapter 1, we might want to test these different predictions independently.

A theory that predicts only (a) has been described by Goss (1955). That theory predicts that Phase 1 training should facilitate learning about the first cue in Phase 2 because Phase 1 training has given that cue "acquired distinctiveness". When the first cue is presented during Phase 2 the previously trained Phase 1 response occurs covertly. Stimuli arising from the covertly occurring response combine with the stimulus presented by the experimenter, increasing its distinctiveness and allowing more rapid learning. This theory predicts increased learning about the first cue in the Discrimination Group, but taken alone it does not seem to predict decreased learning about the second cue. To evaluate this theory, also, we will want to distinguish between increased learning about the first cue in the Discrimination Group and decreased learning about the second cue.

<u>Alternative explanations of reduced control</u>.* We have argued that even in the two-task design it is important to evaluate independently the question of whether the Discrimination Group acquires less control by the added cue in Phase 2 than does the Control Group. The theory of Sutherland predicts that this will occur, while the theory of Goss does not appear to. We turn now to the following question: if decreased learning about the second cue did occur, would this be evidence that Sutherland's theory is correct, or might such decreased learning result from other unsuspected factors?

In fact, both Mackintosh (1965a) and Sutherland & Holgate (1966) found the predicted decrease to occur. In each experiment the Discrimination Group showed less control by the added cue after Phase 2 than did the Control Group. Indices of control by orientation in the experiment by Mackintosh (1965a, Exp. 1) were .83 in the Discrimination Group (his Group BW) and .92 in the Control Group ($P<.05$). Indices of control by orientation in the experiment by Sutherland & Holgate (1966, Exp. 6) were .71 in the Discrimination Group (their Group A) and .86 in the Control Group ($P<.05$ as calculated from data shown in their Fig. 2). Although these findings can be explained by Sutherland's (1964a) theory, they can also be explained in another way. They can be explained if we assume that Goss' (1955) theory (or only that part of Sutherland's theory that predicts increased learning about the first cue) is correct, and that in addition other factors are at work.

Assume that the theory of Goss is correct, and that the

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[*] The point of this section is to suggest certain problems in interpreting results of two-task experiments. The problems considered here follow from the distinctions made in Chapter 2. Other problems that could be mentioned include the complexity of the situation used; the possibility that task 1 learning affects task 2 learning directly via the acquisition of instrumental orienting behavior (this is quite likely: see Siegel, 1967); and the possibility that the test for stimulus control does not measure only control over the task 2 response (see the preceding footnote).

Discrimination Group learns more about the first cue in Phase 2 than does the Control Group because that cue has "acquired distinctiveness" for the Discrimination Group. Given this assumption, several other processes could cause an additional decrease in control by the added cue to be observed. In fact, all but one of the alternative explanations of reduced control described in Chapter 2 could work to cause this result. The increased control by the first cue could cause a decrease in control by the added cue as a result of an interaction on the test for stimulus control. Another possibility is that some factor might work to reduce the control acquired by both cues - training a prior successive discrimination, for example, might very well cause slower learning about <u>any</u> cue in a subsequent simultaneous discrimination. If this occurred, we might find very little increase in control by the first cue in the Discrimination Group as compared to the Control Group. The facilitative effect of acquired distinctiveness in the Discrimination Group would be reduced or entirely cancelled out by the overall disruptive effect of having received prior successive discrimination training. This same disruptive effect might cause the Discrimination Group to learn significantly <u>less</u> about the second cue.

This line of speculation predicts that the Discrimination Group will learn no more about the first cue than the Control Group, but will learn less about the second cue. This was in fact the result in the experiment by Mackintosh (1965a) and in the experiment by Sutherland & Holgate (1966). In neither experiment was the average control by the first cue greater in the Discrimination Group than in Control Group. Since both the theory of Sutherland (1964a) and that of Goss (1955) predict greater control in the Discrimination Group, it does seem possible that some aspect of the Phase 1 training received by the Discrimination Group reduced the acquisition of control by <u>both</u> cues during Phase 2. In fact, Sutherland & Holgate (1966) found it necessary to give extra Phase 2 training to the Discrimination Group, reporting that "the additional trials were necessary because in [the Discrimination Group] the two-cue problem was learned slightly more slowly than in [the Control Group]" (p. 203).

Finally, if acquired distinctiveness facilitates learning about the first cue in the Discrimination Group, the S- response explanation again becomes important. If the Discrimination Group learns faster than the Control Group in Phase 2 as a result of its Phase 1 training, it will make fewer S- responses than the Control Group, and this in turn may cause it to acquire less control by the added cue. An acquired distinctiveness of cues hypothesis, coupled with the S- response hypothesis that was described in detail in the previous section, predicts that Phase 1 training to discriminate on the basis of the first cue will lead to both increased learning about the first cue and decreased learning about the second cue in Phase 2. In fact, the Discrimination Group in the experiment by Mackintosh (1965a) did make fewer S- responses than the Control Group. The difference does not appear large, but the possibility that it had an effect cannot be ruled out; no measure of its statistical significance is given. Sutherland & Holgate (1966) do not report the number of S- responses that occurred in their Control Group.

Conclusions

Even in the two-task design, then, it seems important to distinguish increased learning about the first cue in the Discrimination Group from decreased learning about the second cue. If some mechanism such as acquired distinctiveness of cues produces increased learning about the first cue, several additional factors could work to cause an apparent decrease in learning about the second cue. First, certain factors might make responding on the test for stimulus control an unfair index of the learning that occurred in Phase 2. Second, even if the Discrimination Group did learn less about the added cue, it is possible that this reduced learning was a result of some general factor that reduced learning about both cues in Phase 2. Finally, faster learning about the first cue might reduce learning about the second cue indirectly, by reducing the number of S- responses occurring during Phase 2.

This thesis has dealt with a number of factors which, singly or in interaction, might affect the acquisition and manifestation of stimulus control over a response. In this final section we have argued that these factors might be at work in the two-task design, as well as in the simpler blocking design described in Chapter 2. Much of the argument has been speculative, but it does seem at least a possibility that some of the factors described do indeed have effects. It should be of value to take these factors explicitly into account in the design and analysis of future experiments. One way to do this is to use additional control groups, as was done in Experiment 1; other ways will probably be developed. Whatever the precise tactics used, an explicit attempt to evaluate these factors should improve our understanding of what is involved in the process of discrimination learning.

APPENDIX

Experiment 1: Learning Data

Number of response units completed on positive and negative trials[1]

Subject	DAY								
	2	3	4	5	6	7	8	9	10
Discrimination Group									
(#19)	60/--	60/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40
#17	60/--	60/--	59/--	60/--	40/40	39/40	40/40	39/38	37/32
#18	58/--	58/--	58/--	60/--	40/38	39/39	40/40	40/40	40/40
#37	60/--	60/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40
#40	60/--	60/--	60/--	60/--	40/40	40/40	40/40	38/27	40/19
#42	60/--	57/--	58/--	59/--	39/38	40/40	40/40	40/40	40/40
Median	60/--	60/--	59/--	60/--	40/40	40/40	40/40	40/40	40/40
Not Run Group									
#27	60/--	56/--	60/--	59/--	NOT RUN				
#29	60/--	58/--	59/--	60/--					
#30	60/--	60/--	60/--	60/--					
#47	60/--	59/--	60/--	60/--					
#48	60/--	54/--	59/--	58/--					
#49	60/--	60/--	60/--	60/--					
Mdn	60/--	59/--	60/--	60/--					
S+ Only Group									
#21	60/--	60/--	57/--	59/--	39/--	37/--	35/--	37/--	32/--
#22	60/--	60/--	60/--	58/--	40/--	40/--	40/--	38/--	40/--
#23	58/--	57/--	59/--	60/--	40/--	40/--	40/--	40/--	40/--
#43	41/--	59/--	60/--	60/--	40/--	40/--	37/--	40/--	40/--
#44	60/--	58/--	60/--	60/--	39/--	40/--	40/--	31/--	30/--
#46	60/--	60/--	60/--	60/--	40/--	40/--	40/--	40/--	40/--
Mdn	60/--	59/--	60/--	60/--	40/--	40/--	40/--	39/--	40/--
Partial Group									
#6	58/--	60/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40
#74	60/--	60/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40
#16	59/--	58/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40
#32	57/--	58/--	35/--	54/--	40/40	40/39	40/40	40/40	39/40
#33	58/--	60/--	60/--	59/--	40/40	40/40	39/40	40/40	40/40
#34	60/--	60/--	54/--	60/--	40/40	40/40	40/40	40/40	40/40
Mdn	59/--	60/--	60/--	60/--	40/40	40/40	40/40	40/40	40/40

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[1] Notes: 1) The number to the left of the slash indicates response units completed on positive trials; the number to the right of the slash indicates response units completed on negative trials. 2) The data for #19 are included here. They are not included in the statistical tests reported in the text.

Experiment 1: Learning Data

Number of response units completed

on positive and negative trials

(continued)

Subject				DAY						
	11	12	13	14	15	16	17	18	19	20
Discrimination Group										
(#19)	39/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40
#17	36/16	40/11	40/12	39/24	37/12	40/ 4	40/ 2	40/ 1	40/ 0	40/ 1
#18	37/37	40/40	40/40	40/35	40/37	40/25	40/21	40/ 1	39/ 3	40/ 1
#37	40/30	40/11	40/13	40/ 7	40/20	40/19	40/ 2	40/ 1	40/ 2	40/ 2
#40	39/ 5	40/ 4	40/ 2	40/29	40/12	40/ 1	40/ 0	40/ 4	40/ 1	40/ 4
#42	40/40	40/40	39/33	40/40	40/19	40/ 4	40/ 2	40/ 5	40/ 2	40/ 2
Mdn	39/33	40/25	40/23	40/32	40/19	40/11	40/ 2	40/ 3	40/ 2	40/ 2
Not Run Group										
				NOT RUN						
S+ Only Group										
#21	38/--	39/--	38/--	37/--	39/--	37/--	38/--	38/--	40/--	39/--
#22	40/--	40/--	40/--	38/--	40/--	40/--	40/--	40/--	40/--	40/--
#23	40/--	40/--	40/--	40/--	40/--	40/--	40/--	39/--	39/--	40/--
#43	40/--	40/--	40/--	39/--	40/--	40/--	40/--	40/--	40/--	40/--
#44	40/--	18/--	39/--	40/--	40/--	40/--	40/--	39/--	40/--	40/--
#46	40/--	40/--	40/--	40/--	40/--	40/--	40/--	40/--	40/--	40/--
Mdn	40/--	40/--	40/--	39/--	40/--	40/--	40/--	39/--	40/--	40/--
Partial Group										
#6	40/40	40/40	40/40	40/40	40/40	40/40	40/40	39/40	40/40	40/40
#74	40/40	39/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40
#16	40/40	40/40	40/40	38/37	33/35	34/30	33/30	25/27	11/14	17/16
#32	40/40	40/40	39/40	38/40	39/40	40/39	40/40	40/40	40/40	40/40
#33	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40
#34	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	39/40
Mdn	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40	40/40

Experiment 1: Learning Data

Number of response units completed on positive and negative trials

(Phase 2)

Subject	DAY										
	21	22	23	24	25	26	27	28	29	30	31
Discrimination Group											
(#19)	40/40	40/28	40/ 1	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 2	40/31
#17	40/ 0	40/ 0	40/ 2	39/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	39/ 0
#18	37/ 4	40/ 1	37/ 1	39/ 1	40/ 0	40/ 1	40/ 0	40/ 2	40/ 0	40/ 0	40/ 0
#37	40/ 1	40/ 2	40/ 6	40/ 1	40/ 0	39/ 0	39/ 1	40/ 1	40/ 0	40/ 4	40/ 0
#40	29/ 1	40/ 1	40/ 0	40/ 0	40/ 1	40/ 0	40/ 0	40/ 2	40/ 2	40/ 0	40/ 0
#42	40/ 2	40/ 0	39/ 3	40/ 0	40/ 2	40/ 0	40/ 0	40/ 0	40/ 0	40/28	40/ 8
Mdn	40/ 1	40/ 1	40/ 1	40/ 0	40/ 0	40/ 0	40/ 0	40/ 1	40/ 0	40/ 1	40/ 0
Not Run Group											
#27	37/39	40/40	40/40	40/40	39/ 2	36/ 2	40/ 4	40/ 0	40/ 0	39/ 6	40/ 0
#29	39/40	40/40	40/40	39/36	39/37	40/31	40/19	40/18	40/11	40/27	40/19
#30	31/33	39/39	40/40	40/40	38/37	35/30	40/15	40/ 6	40/ 1	40/10	40/ 8
#47	39/40	40/39	39/40	40/17	40/ 1	40/ 1	40/ 0	39/ 0	39/ 1	40/ 2	40/16
#48	40/40	40/40	40/39	40/27	40/ 5	40/ 6	40/ 4	40/ 3	40/ 2	40/ 0	40/ 1
#49	40/40	40/40	40/35	40/ 7	40/ 0	40/ 1	40/ 1	40/ 1	40/ 1	40/ 1	40/ 1
Mdn	39/40	40/40	40/40	40/31	39/ 3	40/ 4	40/ 4	40/ 2	40/ 1	40/ 4	40/ 5
S+ Only Group											
#21	40/40	40/40	40/33	40/ 5	40/ 0	40/ 0	39/ 0	40/ 0	40/ 0	40/ 0	40/ 1
#22	40/39	40/ 5	40/ 3	40/ 1	40/ 0	40/ 0	40/ 1	40/ 0	40/ 0	40/ 0	40/ 0
#23	39/39	36/22	40/12	40/ 4	40/ 2	40/ 0	40/ 4	40/ 3	40/ 1	40/10	40/ 5
#43	33/33	40/40	40/30	40/ 8	40/ 1	40/ 0	40/ 1	40/ 1	40/ 0	40/ 1	40/ 0
#44	40/40	40/39	40/31	40/16	40/ 9	40/ 4	40/ 2	40/ 2	40/ 2	40/ 2	40/ 0
#46	40/40	40/37	40/32	40/16	40/ 1	40/ 1	40/ 3	40/ 3	40/ 2	40/ 0	40/ 1
Mdn	40/39	40/38	40/31	40/ 7	40/ 1	40/ 0	40/ 1	40/ 1	40/ 1	40/ 1	40/ 1
Partial Group											
# 6	27/30	40/40	40/40	40/40	40/40	40/20	40/ 4	40/ 0	40/ 0	40/ 0	40/ 0
#74	40/40	40/40	40/40	40/ 7	40/ 1	40/ 0	40/ 2	40/ 2	40/ 0	40/ 0	40/ 3
#16	29/37	29/29	38/35	39/33	19/ 9	27/ 1	34/ 3	35/ 1	35/ 0	31/ 0	36/ 1
#32	36/34	40/39	40/32	40/ 6	40/ 1	39/ 0	40/ 0	36/ 1	39/10	37/ 1	39/ 0
#33	40/40	40/40	40/40	40/40	40/34	36/ 3	39/ 5	40/ 3	39/ 0	38/ 4	40/11
#34	40/39	40/40	40/40	40/40	40/34	40/19	40/11	40/13	40/ 6	39/ 4	40/ 2
Mdn	38/38	40/40	40/40	40/37	40/21	39/ 2	40/ 3	40/ 1	39/ 0	39/ 1	40/ 1

Experiment 1: Test Data

Total responses to each stimulus

on first test day

Subject	TRIAL STIMULUS								
	TⓇ	TⒼ	TⓌ	NⓇ	NⒼ	NⓌ	SⓇ	SⒼ	SⓌ
Discrimination Group									
#17	47	0	23	36	0	11	53	0	12
#18	45	4	19	49	0	11	65	11	12
#37	89	1	37	75	0	17	88	0	15
#40	53	0	5	32	0	5	48	0	10
#42	70	14	37	48	3	24	62	11	39
Mean	60.8	3.8	24.2	48.0	0.6	13.6	63.2	4.4	17.6
Not Run Group									
#27	39	16	32	24	2	29	44	10	18
#29	119	95	108	61	5	20	130	33	99
#30	73	18	33	67	7	31	72	11	35
#47	63	10	26	12	5	3	34	3	19
#48	38	3	16	25	0	8	19	0	3
#49	61	10	32	3	0	0	37	6	12
Mean	65.5	25.3	41.2	32.0	3.2	15.2	56.0	10.5	31.0
S+ Only Group									
#21	50	20	50	5	0	1	43	5	23
#22	78	0	31	22	0	0	60	0	12
#23	74	41	61	30	0	0	73	64	56
#43	83	3	23	7	0	0	34	1	8
#44	49	40	40	16	0	1	42	9	16
#46	96	21	47	8	0	2	86	21	47
Mean	71.7	20.8	42.0	14.7	0.0	0.7	56.3	16.7	27.0
Partial Group									
# 6	101	2	42	47	0	9	83	5	36
#74	93	24	59	49	0	4	83	8	47
#16	72	22	36	39	10	30	51	11	62
#32	74	1	29	60	4	13	46	1	25
#33	132	41	99	45	4	10	77	39	29
#34	85	8	55	42	1	1	66	12	41
Mean	92.8	16.3	53.3	47.0	3.2	11.2	67.7	12.7	40.0

Experiment 1: Test Data

Responses summed over stimuli

on first test day

Subject	all Ⓡ trials	all Ⓖ trials	all Ⓦ trials	all T trials	all N trials	all S trials	all trials
Discrimination Group							
#17	136	0	46	70	47	65	182
#18	159	15	42	68	60	88	216
#37	252	1	69	127	92	103	322
#40	133	0	20	58	37	58	153
#42	180	28	100	121	75	112	308
Mean	172.0	8.8	55.4	88.8	62.2	85.2	236.2
Not Run Group							
#27	107	28	79	87	55	72	214
#29	310	133	227	322	86	262	670
#30	212	36	99	124	105	118	347
#47	109	18	48	99	20	56	175
#48	82	3	27	57	33	22	112
#49	101	16	44	103	3	55	161
Mean	153.5	39.0	87.3	132.0	50.3	97.5	279.8
S+ Only Group							
#21	98	25	74	120	6	71	197
#22	160	0	43	109	22	72	203
#23	177	105	117	176	30	193	399
#43	124	4	31	109	7	43	159
#44	107	49	57	129	17	67	213
#46	190	42	96	164	10	154	328
Mean	142.7	37.5	69.7	134.5	15.3	100.0	249.8
Partial Group							
# 6	231	7	87	145	56	124	325
#74	225	32	110	176	53	138	367
#16	162	43	128	130	79	124	333
#32	180	6	67	104	77	72	253
#33	254	84	138	272	59	145	476
#34	193	21	97	148	44	119	311
Mean	207.5	32.2	104.5	162.5	61.3	120.3	344.2

Experiment 1 : Test Data

Total responses to each stimulus

on second test day

Subject	TRIAL STIMULUS								
	T Ⓡ	T Ⓖ	T Ⓦ	N Ⓡ	N Ⓖ	N Ⓦ	S Ⓡ	S Ⓖ	S Ⓦ
Discrimination Group									
#17	2	0	1	10	0	0	4	1	0
#18	13	2	2	22	0	8	29	0	1
#37	65	3	26	49	2	21	41	2	16
#40	25	0	0	12	0	4	26	1	2
#42	37	4	11	13	0	2	34	3	8
Mean	28.4	1.8	8.0	21.2	0.4	7.0	26.8	1.4	5.4
Not Run Group									
#27	10	0	1	5	0	0	6	1	1
#29	70	26	75	20	0	0	86	20	48
#30	51	15	24	42	8	2	54	21	22
#47	53	4	9	11	1	5	19	4	9
#48	44	0	4	13	0	0	0	0	0
#49	24	2	20	0	0	0	10	5	14
Mean	42.0	7.8	22.2	15.2	1.5	1.2	29.2	8.5	15.7
S+ Only Group									
#21	13	0	17	8	0	0	8	1	0
#22	1	0	0	0	0	0	0	0	0
#23	11	8	15	0	0	0	13	3	11
#43	23	0	25	3	0	0	14	0	0
#44	32	24	13	0	0	0	18	7	7
#46	15	0	7	0	0	2	8	2	8
Mean	15.8	5.3	12.8	1.8	0.0	0.3	10.2	2.2	4.3
Partial Group									
# 6	20	1	8	15	0	0	21	0	9
#74	0	0	5	0	0	0	0	1	0
#16	54	4	24	39	2	6	27	1	27
#32	22	1	9	19	0	4	27	2	18
#33	47	19	25	13	0	1	27	6	9
#34	16	0	16	1	2	0	21	0	8
Mean	26.5	4.2	14.5	14.5	0.7	1.8	20.5	1.7	11.8

Experiment 1: Test Data

Responses summed over stimuli on second test day

Subject	all Ⓡ trials	all Ⓖ trials	all Ⓦ trials	all T trials	all N trials	all S trials	all trials
Discrimination Group							
#17	16	1	1	3	10	5	18
#18	64	2	11	17	30	30	77
#37	155	7	63	94	72	59	225
#40	63	1	6	25	16	29	70
#42	84	7	21	52	15	45	112
Mean	76.4	3.6	20.4	38.2	28.6	33.6	100.4
Not Run Group							
#27	21	1	2	11	5	8	24
#29	176	46	123	171	20	154	345
#30	147	44	48	90	52	97	239
#47	83	9	23	66	17	32	115
#48	57	0	4	48	13	0	61
#49	34	7	34	46	0	29	75
Mean	86.3	17.8	39.0	72.0	17.8	53.3	143.2
S+ Only Group							
#21	29	1	17	30	8	9	47
#22	1	0	0	1	0	0	1
#23	24	11	26	34	0	27	61
#43	40	0	25	48	3	14	65
#44	50	31	20	69	0	32	101
#46	23	2	17	22	2	18	42
Mean	27.8	7.5	17.5	34.0	2.2	16.7	52.8
Partial Group							
# 6	56	1	17	29	15	30	74
#74	0	1	5	5	0	1	6
#16	120	7	57	82	47	55	184
#32	68	3	31	32	23	47	102
#33	87	25	35	91	14	42	147
#34	38	2	24	32	3	29	64
Mean	61.5	6.5	28.2	45.2	17.0	34.0	96.2

Experiment 1: Test Data

Total responses to each stimulus

on both test days

Subject	TRIAL STIMULUS								
	T Ⓡ	T Ⓖ	T Ⓦ	N Ⓡ	N Ⓖ	N Ⓦ	S Ⓡ	S Ⓖ	S Ⓦ
Discrimination Group									
#17	49	0	24	46	0	11	57	1	12
#18	58	6	21	71	0	19	94	11	13
#37	154	4	63	124	2	38	129	2	31
#40	78	0	5	44	0	9	74	1	12
#42	107	18	48	61	3	26	96	14	47
Mean	89.2	5.6	32.2	69.2	1.0	20.6	90.0	5.8	23.0
Not Run Group									
#27	49	16	33	29	2	29	50	11	19
#29	189	121	183	81	5	20	216	53	147
#30	124	33	57	109	15	33	126	32	57
#47	116	14	35	23	6	8	53	7	28
#48	82	3	20	38	0	8	19	0	3
#49	85	12	52	3	0	0	47	11	26
Mean	107.5	33.2	63.3	47.2	4.7	16.3	85.2	19.0	46.7
S+ Only Group									
#21	63	20	67	13	0	1	51	6	23
#22	79	0	31	22	0	0	60	0	12
#23	85	49	76	30	0	0	86	67	67
#43	106	3	48	10	0	0	48	1	8
#44	81	64	53	16	0	1	60	16	23
#46	111	21	54	8	0	4	94	23	55
Mean	87.5	26.2	54.8	16.5	0.0	1.0	66.5	18.8	31.3
Partial Group									
# 6	121	3	50	62	0	9	104	5	45
#74	93	24	64	49	0	4	83	9	47
#16	126	26	60	78	12	36	78	12	89
#32	96	2	38	79	4	17	73	3	43
#33	179	60	124	58	4	11	104	45	38
#34	101	8	71	43	3	1	87	12	49
Mean	119.3	20.5	67.8	61.5	3.8	13.0	88.2	14.3	51.8

Experiment 1: Test Data

Responses summed over stimuli

on both test days

Subject	all Ⓡ trials	all Ⓖ trials	all Ⓦ trials	all T trials	all N trials	all S trials	all trials
Discrimination Group							
#17	152	1	47	73	57	70	200
#18	223	17	53	85	90	118	293
#37	407	8	132	221	164	162	547
#40	196	1	26	83	53	87	223
#42	264	35	121	173	90	157	420
Mean	248.4	12.4	75.8	127.0	90.8	118.8	336.6
Not Run Group							
#27	128	29	81	98	60	80	238
#29	486	179	350	493	106	416	1015
#30	359	80	147	214	157	215	586
#47	192	27	71	165	37	88	290
#48	139	3	31	105	46	22	173
#49	135	23	78	149	3	84	236
Mean	239.8	56.8	126.3	204.0	68.2	150.8	423.0
S+ Only Group							
#21	127	26	91	150	14	80	244
#22	161	0	43	110	22	72	204
#23	201	116	143	210	30	220	460
#43	164	4	56	157	10	57	224
#44	157	80	77	198	17	99	314
#46	213	44	113	186	12	172	370
Mean	170.5	45.0	87.2	168.5	17.5	116.7	302.7
Partial Group							
# 6	287	8	104	174	71	154	399
#74	225	33	115	181	53	139	373
#16	282	50	185	212	126	179	517
#32	248	9	98	136	100	119	355
#33	341	109	173	363	73	187	623
#34	231	23	121	180	47	148	375
Mean	269.0	38.7	132.7	207.7	78.3	154.3	440.3

Experiment 1: Indices of auditory control

	Multiplicative Indices				Additive Indices			
Subject	$\frac{T\textcircled{R}}{T\textcircled{R}+N\textcircled{R}}$	$\frac{T\textcircled{G}}{T\textcircled{G}+N\textcircled{G}}$	$\frac{T\textcircled{W}}{T\textcircled{W}+N\textcircled{W}}$	$\frac{T}{T+N}$	$T\textcircled{R}-N\textcircled{R}$	$T\textcircled{G}-N\textcircled{G}$	$T\textcircled{W}-N\textcircled{W}$	$T-N$
Discrimination Group								
#17	.516	--	.686	.561	3	0	13	16
#18	.450	1.000	.525	.486	-13	6	2	-5
#37	.554	.667	.624	.574	30	2	25	57
#40	.639	--	.357	.610	34	0	-4	30
#42	.637	.857	.649	.658	46	15	22	83
Mean	.559	.841	.568	.578	20.0	4.6	11.6	36.2
Not Run Group								
#27	.628	.889	.532	.620	20	14	4	38
#29	.700	.960	.901	.823	108	116	163	387
#30	.532	.687	.633	.577	15	18	24	57
#47	.835	.700	.814	.817	93	8	27	128
#48	.683	1.000	.714	.695	44	3	12	59
#49	.966	1.000	1.000	.980	82	12	52	146
Mean	.724	.873	.766	.752	60.3	28.5	47.0	135.8
S+ Only Group								
#21	.829	1.000	.985	.915	50	20	66	136
#22	.782	--	1.000	.833	57	0	31	88
#23	.739	1.000	1.000	.875	55	49	76	180
#43	.914	1.000	1.000	.940	96	3	48	147
#44	.835	1.000	.981	.921	65	64	52	181
#46	.933	1.000	.931	.939	103	21	50	174
Mean	.839	1.000	.983	.904	71.0	26.2	53.8	151.0
Partial Group								
# 6	.661	1.000	.847	.710	59	3	41	103
#74	.655	1.000	.941	.773	44	24	60	128
#16	.618	.684	.625	.627	48	14	24	86
#32	.549	.333	.691	.576	17	-2	21	36
#33	.755	.937	.919	.833	121	56	113	290
#34	.701	.727	.986	.793	58	5	70	133
Mean	.657	.780	.835	.719	57.8	16.7	54.8	129.3
Mann-Whitney U								
D vs S+	0**	-	0**	0**	0**	5-7	0**	0**
D vs N	5	-	5	3*	7	5	7	4-5
D vs P	5	-	2*	3*	4	5	3*	2*
S+vs N	9-10	-	3-6*	6	>10	>10	9-10	9
S+vs P	1**	-	4*	0-1**	>10	>10	>10	9
N vs P	>10	-	>10	>10	>10	>10	>10	>10

* P<.05
** P<.01

Experiment 1: Indices of Visual Control

	Multiplicative Indices				Additive Indices			
Subject	TⓇ / (TⓇ+TⒼ)	NⓇ / (NⓇ+NⒼ)	SⓇ / (SⓇ+SⒼ)	Ⓡ / (Ⓡ+Ⓖ)	TⓇ-TⒼ	NⓇ-NⒼ	SⓇ-SⒼ	Ⓡ-Ⓖ
Discrimination Group								
#17	1.000	1.000	.983	.993	49	46	56	151
#18	.906	1.000	.895	.929	52	71	83	206
#37	.975	.984	.985	.981	150	122	127	399
#40	1.000	1.000	.987	.995	78	44	73	195
#42	.856	.953	.873	.882	89	58	82	229
Mean	.947	.987	.945	.956	83.6	68.2	84.2	236.0
Not Run Group								
#27	.754	.935	.820	.815	33	27	39	99
#29	.610	.942	.803	.731	68	76	163	307
#30	.790	.879	.797	.818	91	94	94	279
#47	.892	.793	.883	.877	102	17	46	165
#48	.965	1.000	1.000	.979	79	38	19	136
#49	.876	1.000	.810	.854	73	3	36	112
Mean	.815	.925	.852	.846	74.3	42.5	66.2	183.0
S+ Only Group								
#21	.759	1.000	.895	.830	43	13	45	101
#22	1.000	1.000	1.000	1.000	79	22	60	161
#23	.634	1.000	.562	.634	36	30	19	85
#43	.972	1.000	.979	.976	103	10	47	160
#44	.559	1.000	.789	.662	17	16	44	77
#46	.841	1.000	.803	.829	90	8	71	169
Mean	.794	1.000	.838	.822	61.3	16.5	47.7	125.5
Partial Group								
# 6	.976	1.000	.954	.973	118	62	99	279
#74	.795	1.000	.902	.872	69	49	74	192
#16	.829	.867	.867	.849	100	66	66	232
#32	.979	.952	.961	.965	94	75	70	239
#33	.749	.935	.698	.758	119	54	59	232
#34	.927	.935	.879	.909	93	40	75	208
Mean	.876	.948	.877	.888	98.8	57.7	73.8	230.3
Mann-Whitney U								
D vs S+	5-7	-	9	7	>10	0**	2*	3*
D vs N	4	-	6	2*	>10	8	9	9
D vs P	8	-	7	5	8	>10	>10	10
S+vs N	>10	-	>10	>10	>10	9	>10	>10
S+vs P	>10	-	>10	>10	6	0**	4*	0**
N vs P	>10	-	>10	>10	7	>10	>10	>10

* P<.05
** P<.01

Experiment 1: Trial Analyses

	T Ⓡ > N Ⓡ		T Ⓖ > N Ⓖ		T Ⓦ > N Ⓦ		TOTAL T > N	
Subject	PROPORTION	DECIMAL	PROPORTION	DECIMAL	PROPORTION	DECIMAL	PROPORTION	DECIMAL
Discrimination Group								
#17	5/13*	.385	0/ 0	-	8/ 9	.889	13/22	.591
#18	5/13	.385	3/ 3	1.000	6/10	.600	14/26	.538
#37	11/13	.846	3/ 5	.600	11/16	.687	25/34	.735
#40	11/11	1.000	0/ 0	-	2/ 6	.333	13/17	.765
#42	15/16	.937	6/ 7	.857	6/ 7	.857	27/30	.900
Mean		.711		.819		.673		.706
Not Run Group								
#27	7/10	.700	4/ 5	.800	5/ 7	.714	16/22	.727
#29	15/17	.882	17/17	1.000	18/18	1.000	50/52	.962
#30	11/17	.647	7/10	.700	7/13	.538	25/40	.625
#47	15/17	.882	8/10	.800	12/13	.923	35/40	.875
#48	8/ 9	.889	1/ 1	1.000	3/ 4	.750	12/14	.857
#49	12/12	1.000	6/ 6	1.000	8/ 8	1.000	26/26	1.000
Mean		.833		.883		.821		.841
S+ Only Group								
#21	7/ 8	.875	3/ 3	1.000	7/ 8	.875	17/19	.895
#22	10/10	1.000	0/ 0	-	5/ 5	1.000	15/15	1.000
#23	9/11	.818	8/ 8	1.000	13/13	1.000	30/32	.937
#43	13/14	.929	2/ 2	1.000	10/10	1.000	25/26	.962
#44	7/ 8	.875	10/10	1.000	12/12	1.000	29/30	.967
#46	11/11	1.000	6/ 6	1.000	10/10	1.000	27/27	1.000
Mean		.916		1.000		.979		.960
Partial Group								
# 6	11/13	.846	3/ 3	1.000	9/ 9	1.000	23/25	.920
#74	6/ 9	.667	5/ 5	1.000	10/10	1.000	21/24	.875
#16	12/17	.706	7/ 9	.778	11/15	.733	30/41	.732
#32	8/14	.571	1/ 3	.333	7/12	.583	16/29	.552
#33	15/16	.937	10/11	.909	15/15	1.000	40/42	.952
#34	8/ 9	.889	5/ 6	.833	10/10	1.000	23/25	.920
Mean		.769		.809		.886		.825

Mann-Whitney U	
D vs S+	1**
D vs N	8
D vs P	8
S+vs N	6-9
S+vs P	4*
N vs P	>10

* P <.05
** P <.01

*There were 13 cases throughout the test in which a different number of responses occurred to a T Ⓡ trial than to its matched N Ⓡ trial; in 5 of these cases more responding occurred to the T Ⓡ trial.

Experiment 1: Intertrial Responses

Number of Intertrial Responses per Session

	SUBJECT																						
Session	#17	#18	#37	#40	#42	#27	#29	#30	#47	#48	#49	#21	#22	#23	#43	#44	#46	#6	#74	#16	#32	#33	#34
2	0	0	0	0	0	0	0	4	2	5	289	0	0	3	3	6	290	-	24	0	0	57	3
3	0	0	0	0	0	0	6	0	1	1	17	0	0	9	2	4	9	0	0	1	0	0	0
4	0	3	0	0	1	0	1	0	0	1	13	0	0	0	0	0	8	1	0	0	4	1	1
5	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	0	0	1							0	0	1	0	2	0	0	0	0	0	0	0
7	1	0	0	0	0							0	0	2	0	0	0	0	0	1	0	0	0
8	0	1	0	0	0							1	0	0	2	0	0	0	0	0	0	3	0
9	1	0	1	0	0							2	1	0	0	3	0	0	1	0	0	0	0
10	3	3	0	0	0							1	0	0	0	1	0	0	0	0	1	0	0
11	0	1	2	0	0			NOT				0	0	0	0	1	0	0	0	0	0	0	0
12	0	0	1	0	0							1	0	0	1	0	0	0	2	0	0	9	0
13	2	0	3	0	0			RUN				2	0	0	1	3	0	0	1	0	0	0	0
14	0	0	3	1	0							1	1	0	1	0	0	0	0	0	1	2	0
15	0	12	-	-	-							1	1	1	0	1	0	0	0	1	0	12	0
16	0	5	10	7	2							1	9	3	0	8	2	1	3	2	0	6	2
17	1	13	2	0	0							0	0	0	0	0	0	0	8	10	1	5	2
18	0	4	1	3	1							0	3	1	0	1	0	1	1	8	0	1	0
19	1	3	1	4	4							0	3	1	0	5	0	0	2	7	0	8	2
20	0	3	3	3	2							2	6	2	0	4	2	0	7	13	0	16	5
21	0	3	0	5	2	1	31	4	2	7	12	0	3	2	1	0	0	0	7	5	1	1	0
22	0	7	1	8	5	0	7	2	0	3	3	0	3	3	0	8	3	0	2	10	1	9	4
23	0	2	0	3	2	0	6	2	0	1	2	0	4	2	0	6	1	0	2	4	3	5	1
24	0	0	0	4	1	0	7	1	0	4	11	1	1	2	2	4	2	0	4	2	1	10	0
25	0	0	1	0	0	1	6	2	0	1	6	0	0	2	3	4	1	0	0	4	3	18	2
26	0	1	2	0	2	1	5	4	0	0	1	0	0	1	0	0	0	3	2	2	0	6	6
27	0	0	1	2	3	0	7	4	0	1	2	0	5	1	0	1	0	1	0	3	0	14	0
28	0	7	0	2	2	0	11	1	0	4	2	0	0	1	0	6	1	0	1	0	0	120	3
29	1	2	0	1	1	0	4	2	0	3	1	0	2	4	0	2	0	0	0	1	0	455	1
30	1	0	0	2	2	0	1	1	1	0	0	0	1	0	0	1	3	0	0	2	3	289	0
31	0	1	0	1	1	0	5	2	3	1	1	0	1	2	0	1	3	0	1	1	0	248	0
32	6	6	6	7	4	14	12	9	11	0	1	11	4	4	3	2	16	4	2	13	5	41	4
33	0	20	0	27	17	2	25	20	2	9	3	4	17	14	1	-	9	0	12	12	3	25	15

- signifies no data on intertrial responses for that day

Experiment 2: Learning Data

Number of response units completed

on positive and negative trials

	DAY									
S	1	2	3	4	5	6	7	8	9	10
Discrimination Group										
#9	40/--	40/--	40/--	37/--	40/--	40/39	40/40	40/40	40/40	40/ 8
#21	40/--	39/--	40/--	40/--	40/--	40/37	40/40	40/31	38/15	40/ 4
#35	39/--	40/--	40/--	40/--	40/--	40/40	40/40	39/40	40/37	39/28
#42	38/--	40/--	40/--	40/--	40/--	39/37	40/40	40/40	40/40	40/21
#47	32/--	37/--	40/--	38/--	40/--	40/40	40/33	40/15	40/10	40/ 2
#50	40/--	40/--	40/--	40/--	40/--	40/40	40/40	40/40	40/40	40/40
Mdn	39/--	40/--	40/--	40/--	40/--	40/39	40/40	40/40	40/39	40/15
Control Group										
#41	39/--	40/--	40/--	39/--	39/--	40/33	35/ 9	39/ 9	40/ 1	40/ 0
#46	38/--	40/--	40/--	40/--	40/--	39/38	39/ 7	40/ 1	40/ 1	40/ 1
#49	39/--	40/--	40/--	39/--	40/--	40/38	40/19	40/20	40/ 2	40/ 1
#51	40/--	40/--	40/--	40/--	39/--	40/40	40/22	40/18	40/ 4	40/ 5
Mdn	39/--	40/--	40/--	39/--	39/--	40/38	39/14	40/13	40/ 1	40/ 1

	DAY								Phase 2	
S	11	12	13	14	15	16	17	18	19	20
Discrimination Group										
#9	40/ 6	40/ 0	40/ 9	40/11	40/ 4	N.R.	40/ 1	40/ 5	40/ 1	39/ 1
#21	40/ 7	38/ 8	40/ 5	40/ 3	40/ 5	N.R.	40/ 4	40/ 4	40/ 4	40/ 0
#35	40/16	40/ 7	40/12	40/ 9	40/ 9	test	40/12	40/10	39/ 6	40/ 2
#42	40/ 5	40/ 9	40/ 2	40/ 1	40/ 4	test	40/ 2	40/ 0	40/28*	40/30
#47	40/ 0	40/ 1	40/ 0	40/ 4	40/ 2	test	40/ 2	40/ 0	40/ 6	40/ 0
#50	40/40	40/23	40/ 7	40/ 7	40/ 2	test	40/ 1	40/ 6	39/10	40/ 2
Mdn	40/ 7	40/ 7	40/ 6	40/ 5	40/ 4	-	40/ 2	40/ 5	40/ 6	40/ 1
Control Group										
#41	39/ 0	39/ 0	40/ 0	39/ 1	40/ 0	test	39/ 0	37/ 0	32/ 3	34/ 5
#46	40/ 0	40/ 1	39/ 0	40/ 0	40/ 0	test	40/ 0	40/ 0	40/21	40/30
#49	40/ 2	40/ 1	39/ 1	40/ 2	40/ 0	test	39/ 1	40/ 1	40/ 8	39/ 6
#51	40/ 0	40/ 0	37/ 0	40/ 0	40/ 0	test	40/ 2	40/ 0	38/11	40/ 2
Mdn	40/ 0	40/ 1	39/ 0	40/ 1	40/ 0	-	39/ 1	40/ 0	39/ 9	39/ 5

	DAY									
S	21	22	23	24	25	26	27	28	29	30
Discrimination Group										
#9	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 1	40/ 1	39/ 0	test	40/ 1
#21	40/ 0	40/ 1	40/ 0	40/ 0	40/ 1	40/ 1	39/ 0	40/ 3	test	40/ 1
#35	40/ 6	40/ 4	40/ 3	40/ 3	40/ 1	40/ 0	40/ 1	40/ 0	test	39/ 1
#42	40/11	40/ 5	40/ 1	40/ 1	40/ 1	40/ 0	40/ 0	39/ 0	test	40/ 0
#47	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	40/ 0	test	39/ 0
#50	40/ 1	40/ 1	40/ 1	40/ 0	40/ 1	40/ 1	40/ 0	40/ 1	test	40/ 1
Mdn	40/ 1	40/ 1	40/ 0	40/ 0	40/ 1	40/ 1	40/ 0	40/ 0	-	40/ 1
Control Group										
#41	38/ 8	36/ 0	38/ 0	36/ 0	38/ 0	37/ 0	29/ 0	22/ 0	test	13/ 0
#46	40/32	39/17	40/ 8	40/10	40/11	40/ 3	40/ 4	40/ 1	test	40/ 1
#49	40/ 1	40/ 0	40/ 0	40/ 0	40/ 4	40/ 2	40/ 0	40/ 0	test	40/ 2
#51	39/ 4	40/ 0	40/ 0	40/ 0	39/ 0	30/ 0	38/11	25/ 4	test	26/14
Mdn	39/ 6	39/ 0	40/ 0	40/ 0	39/ 2	39/ 1	39/ 2	33/ 1	-	33/ 1

N.R. = bird not run; test = test for stimulus control given.

*An error caused reinforcement to occur following every S- trial on Day 19, for #42 only. This caused S- responding to occur.

Experiment 2: Test Data

Total responses to each stimulus

Subject	TRIAL STIMULUS								
	T⦶	T⊘	T○	N⦶	N⊘	N○	S⦶	S⊘	S○
Discrimination Group, first test									
#35	4	0	80	0	0	40	3	2	79
#42	0	3	64	0	0	4	0	0	41
#47	0	2	73	0	0	4	0	0	37
#50	6	0	78	0	4	33	0	0	64
Mean	3	1	74	0	1	20	1	1	55
Control Group, first test									
#41	66	39	2	6	0	0	55	12	0
#46	76	8	1	8	0	0	68	1	0
#49	65	44	12	0	0	4	16	10	0
#51	80	74	41	23	11	5	76	56	14
Mean	72	41	14	9	3	2	54	20	3
Discrimination Group, second test									
#9	50	31	74	0	0	6	25	9	51
#21	70	47	68	0	7	2	16	9	14
#35	77	66	64	3	4	5	46	39	21
#42	41	44	24	0	0	0	6	2	1
#47	40	29	33	0	0	0	8	11	7
#50	56	49	56	0	0	1	15	20	24
Mean	56	44	53	1	2	2	19	15	20
Control Group, second test									
#41	26	24	31	4	0	0	20	15	33
#46	64	17	76	8	0	4	62	5	52
#49	61	30	69	3	0	0	10	1	7
#51	31	33	41	0	3	10	23	12	40
Mean	45	26	54	4	1	3	29	8	33

Experiment 2: Test Data

Responses summed over stimuli

subject	all ⦶ trials	all ⊘ trials	all ○ trials	all T trials	all N trials	all S trials	ALL TRIALS
Discrimination Group, first test							
#35	7	2	199	84	40	84	208
#42	0	3	109	67	4	41	112
#47	0	2	114	75	4	37	116
#50	6	4	175	84	37	64	185
Mean	3	3	149	77	21	57	155
Control Group, first test							
#41	127	51	2	107	6	67	180
#46	152	9	1	85	8	69	162
#49	81	54	16	121	4	26	151
#51	179	141	60	195	39	146	380
Mean	135	64	20	127	14	77	218
Discrimination Group, second test							
#9	75	40	131	155	6	85	246
#21	86	63	84	185	9	39	233
#35	126	109	90	207	12	106	325
#42	47	46	25	109	0	9	118
#47	48	40	40	102	0	26	128
#50	71	69	81	161	1	59	221
Mean	75	61	75	153	5	54	212
Control Group, second test							
#41	50	39	64	81	4	68	153
#46	134	22	132	157	12	119	288
#49	74	31	76	160	3	18	181
#51	54	48	91	105	13	75	193
Mean	78	35	91	126	8	70	204

Experiment 2: Indices of Stimulus Control

Subject	Multiplicative indices				Additive indices			
	$\frac{T}{T+N}$	$\frac{TO}{TO+NO}$	$\frac{\Phi}{\Phi+\oslash}$	$\frac{S\Phi}{S\Phi+S\oslash}$	$T-N$	$TO-NO$	$\Phi-\oslash$	$S\Phi-S\oslash$
Discrimination Group, first test								
#35	.68	.67	(.78)	(.60)	44	40	5	1
#42	.94	.94	(.00)	-	63	60	-3	0
#47	.95	.95	(.00)	-	71	69	-2	0
#50	.69	.70	(.60)	-	47	45	2	0
Mean	.82	.81	(.35)	(.60)	57	54	0	0
Control Group, first test								
#41	.95	(1.00)	.71	.82	101	2	76	43
#46	.91	(1.00)	.94	.99	77	1	143	67
#49	.97	.75	.60	.61	117	8	27	6
#51	.83	.89	.56	.58	156	36	38	20
Mean	.91	(.91)	.70	.75	113	12	71	34
Discrimination Group, second test								
#9	.96	.93	.65	.73	149	68	35	16
#21	.95	.97	.58	.64	176	66	23	7
#35	.95	.93	.54	.54	195	59	17	7
#42	1.00	1.00	.51	(.75)	109	24	1	4
#47	1.00	1.00	.55	.42	102	33	8	-3
#50	.99	.98	.51	.43	160	55	2	-5
Mean	.98	.97	.55	.59	149	51	14	4
Control Group, second test								
#41	.95	1.00	.56	.57	77	31	11	5
#46	.93	.95	.86	.93	145	72	112	57
#49	.98	1.00	.71	.91	157	69	43	9
#51	.89	.80	.53	.66	92	31	6	11
Mean	.94	.94	.66	.77	118	51	43	21

Mann-Whitney U

Discrimination Group 2d test vs Control Group 1st test:	3-5	8-12	3	6	5	2*	1**	3
Discrimination Group 2d test vs Control Group 2d test:	3-5	>10	6	5	5	>10	7	5

* P<.05
** P<.02

Note: Parentheses ( ) around a multiplicative index of control indicates that only a small number of responses entered into the calnulation of this index.

Experiment 2: Trial Analyses

Subject	T⦶>T⊘ PROPORTION	N⦶>N⊘ PROPORTION	S⦶>S⊘ PROPORTION	TOTAL ⦶ > ⊘ PROPORTION	TOTAL ⦶ > ⊘ DECIMAL
Discrimination Group, Phase 1					
#35	1/ 1	0/ 0	1/ 2	2/ 3	.667
#42	0/ 1	0/ 0	0/ 0	0/ 1	.000
#47	0/ 1	0/ 0	0/ 0	0/ 1	.000
#50	3/ 3	0/ 1	0/ 1	3/ 5	.600
Mean					.317
Control Group, Phase 1					
#41	9/10	0/ 0	15/15	24/25	.960
#46	18/18	2/ 2	17/17	37/37	1.000
#49	9/10	0/ 0	4/ 8	13/18	.722
#51	4/ 4	7/ 9	8/ 9	19/22	.864
Mean					.887
Discrimination Group, Phase 2					
# 9	7/ 8	2/ 3	10/17	19/28	.679
#21	3/ 7	0/ 0	2/ 3	5/10	.500
#35	8/11	0/ 0	2/ 6	10/17	.588
#42	7/12	0/ 0	1/ 6	8/18	.444
#47	8/10	0/ 0	8/ 9	16/19	.842
#50	12/15	0/ 3	5/ 6	17/24	.708
Mean					.627
Control Group, Phase 2					
#41	7/13	1/ 1	6/ 9	14/23	.609
#46	13/13	2/ 2	17/17	32/32	1.000
#49	12/14	1/ 1	3/ 3	16/18	.889
#51	4/ 7	0/ 1	8/10	12/18	.667
Mean					.791

Mann-Whitney U	
C1 vs D2	1*
C2 vs D2	6

* P <.05

Experiment 2: Intertrial Responses

Number of Intertrial Responses per Session

	SUBJECT									
Session	#9	#21	#35	#42	#47	#50	#41	#46	#49	#51
1	16	7	56	40	0	3	1	0	3	4
2	0	0	1	0	0	1	3	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	1	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	2	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	Not Run		-	0	0	4	0	0	0	1
17	0	0	0	0	1	0	1	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	1	0	0
20	0	0	2	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	1	0	0
22	0	0	0	0	6	0	0	0	0	0
23	0	0	0	0	4	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	1	0	0	0
27	0	0	0	0	0	0	0	0	0	0
28	0	0	1	0	0	0	0	0	0	0
29	1	0	0	0	1	0	0	0	18	0
30	0	0	0	0	0	0	0	0	1	1

Note: Tests for stimulus control given on days 16 and 29.

- no data for this day

Experiment 3: Learning Data

Number of response units completed
on positive and negative trials

PRETRAINING AND PHASE 1

Subject	DAY 2	3	4	5	6	7	8	9	10	11
Discrimination Group										
#4	60/--	60/--	57/--	60/--	40/40	40/40	40/40	40/40	39/34	40/12
#14	60/--	60/--	56/--	57/--	40/37	40/40	40/39	40/18	40/ 3	40/ 0
#20	60/--	57/--	59/--	59/--	38/39	39/36	40/26	23/14	40/ 4	40/ 2
#24	43/--	42/--	---	60/--	40/38	40/40	40/29	38/11	40/ 2	40/ 0
Mdn	60/--	59/--	57/--	59/--	40/39	40/40	40/34	39/16	40/ 3	40/ 1
Control Group										
#31	58/--	60/--	58/--	59/--	40/35	40/36	40/13	40/ 3	40/ 2	test
#34	60/--	57/--	60/--	59/--	40/40	40/40	40/38	40/36	40/30	test
#37	47/--	42/--	15/--	58/--	31/29	39/28	36/10	35/ 8	39/ 3	test
#61	51/--	56/--	58/--	59/--	39/35	40/10	40/ 3	40/ 7	40/ 2	test
Mdn	55/--	57/--	58/--	59/--	39/35	40/32	40/11	40/ 7	40/ 3	---

PHASE 2

Subject	DAY 12	13	14	15	16
Discrimination Group					
#4	40/30	40/ 5	40/ 3	40/ 5	40/ 1
#14	37/ 6	39/ 3	40/ 0	40/ 0	40/ 0
#20	40/14	40/ 6	40/ 3	40/ 4	40/ 4
#24	40/19	40/ 9	39/ 1	40/ 0	40/ 0
Mdn	40/17	40/ 5	40/ 2	40/ 2	40/ 0

Experiment 3: Test Data

	Total Responses to each Stimulus									Responses Summed over Stimuli						
Subject	T⦶	T⊖	T○	N⦶	N⊖	N○	S⦶	S⊖	S○	⦶	⊖	○	T	N	S	ALL TRIALS
Discrimination Group - first test day																
#4	36	35	36	8	0	5	24	15	29	68	50	70	107	13	68	188
#14	28	19	34	0	0	4	20	6	30	48	25	68	81	4	56	141
#20	33	33	36	15	2	0	28	8	16	76	43	52	102	17	52	171
#24	36	30	21	0	0	0	17	9	12	53	39	33	87	0	38	125
Mean	33	29	32	6	1	2	22	9	22	61	39	56	94	9	53	156
Control Group - first test day																
#31	36	21	14	36	9	7	33	15	8	105	45	29	71	52	56	179
#34	31	33	36	31	31	23	36	32	28	98	96	87	100	85	96	281
#37	28	2	24	24	1	10	28	1	24	80	4	58	54	35	53	142
#61	28	20	20	20	0	20	16	17	24	64	37	64	68	40	57	165
Mean	31	19	23	28	10	15	28	16	21	87	45	59	73	53	65	192
Discrimination Group - second test day																
#4	28	24	19	2	0	0	4	6	6	34	30	25	71	2	16	89
#14	7	4	8	0	0	0	0	1	2	7	5	10	19	0	3	22
#20	32	14	20	20	0	0	19	2	2	71	16	22	66	20	23	109
#24	36	29	33	2	0	0	26	7	11	64	36	44	98	2	44	144
Mean	26	18	20	6	0	0	12	4	5	44	22	25	63	6	21	91
Control Group - second test day																
#31	36	4	7	29	1	1	31	6	2	96	11	10	47	31	39	117
#34	28	31	29	28	17	14	30	32	27	86	80	70	88	59	89	236
#37	36	8	15	27	0	0	32	0	12	95	8	27	59	27	44	130
#61	31	14	17	20	6	5	36	23	20	87	43	42	62	31	79	172
Mean	33	14	17	26	6	5	32	15	15	91	35	37	64	37	63	164
Discrimination Group - both test days																
#4	64	59	55	10	0	5	28	21	35	102	80	95	178	15	84	277
#14	35	23	42	0	0	4	20	7	32	55	30	78	100	4	59	163
#20	65	47	56	35	2	0	47	10	18	147	59	74	168	37	75	280
#24	72	59	54	2	0	0	43	16	23	117	75	77	185	2	82	269
Mean	59	47	52	12	1	2	35	13	27	105	61	81	158	15	75	247
Control Group - both test days																
#31	72	25	21	65	10	8	64	21	10	201	56	39	118	83	95	296
#34	59	64	65	59	48	37	66	64	55	184	176	157	188	144	185	517
#37	64	10	39	51	1	10	60	1	36	175	12	85	113	62	97	272
#61	59	34	37	40	6	25	52	40	44	151	80	106	130	71	136	337
Mean	63	33	41	54	16	20	61	31	36	178	81	97	137	90	128	355

Experiment 3: Indices of Stimulus Control after Both Test Days

Subject	Multiplicative indices				Additive indices			
	$\frac{T}{T+N}$	$\frac{T\bigcirc}{T\bigcirc+N\bigcirc}$	$\frac{\Phi}{\Phi+\ominus}$	$\frac{S\Phi}{S\Phi+S\ominus}$	$T-N$	$T\bigcirc-N\bigcirc$	$\Phi-\ominus$	$S\Phi-S\ominus$
Discrimination Group								
#4	.922	.917	.560	.571	163	50	22	7
#14	.961	.913	.647	.741	96	38	25	13
#20	.819	1.000	.713	.825	131	56	88	37
#24	.989	1.000	.609	.729	183	54	42	27
Mean	.923	.957	.632	.717	143	49	44	21
Control Group								
#31	.587	.724	.782	.753	35	13	145	43
#34	.566	.637	.511	.508	44	28	8	2
#37	.646	.796	.936	.984	51	29	163	59
#61	.647	.597	.654	.565	59	12	71	12
Mean	.611	.689	.721	.703	47	21	97	29
Mann-Whitney U:								
	0*	0*	5	9	0*	0*	5	7

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* P<.03

Experiment 3: Intertrial Responses

Number of Intertrial Responses per Session

Session	SUBJECT							
	#4	#14	#20	#24	#31	#34	#37	#61
2	36	17	17	9	3	119	18	35
3	53	5	13	12	7	178	7	35
4	56	3	16	-	6	90	5	48
5	60	7	21	28	24	112	7	53
6	77	16	19	47	30	127	7	63
7	79	50	30	55	49	95	24	42
8	79	66	27	46	43	75	20	41
9	78	39	11	27	43	83	20	46
10	68	42	16	28	31	94	31	43
11	53	34	14	32	33	123	13	29
12	61	17	35	36	16	93	13	29
13	44	11	40	42	39	93	26	67
14	40	14	37	27	52	81	46	60
15	45	10	41	21	48	52	48	49
16	42	15	37	12	22	43	40	44
17	34	22	31	9	42	82	22	35
18	17	2	16	17	23	37	9	30

- no data for this session

Experiment 4: Learning Data

Number of response units completed on positive and negative trials

PRETRAINING AND PHASE 1									
					DAY				
Subject	2	3	4	5	6	7	8	9	10
Discrimination Group									
#2	58/--	60/--	60/--	60/--	40/38	40/33	40/16	40/ 8	40/ 3
#7	49/--	46/--	59/--	59/--	39/36	40/39	40/40	40/40	39/40
#28	58/--	59/--	60/--	59/--	40/39	40/36	39/20	40/11	40/ 6
#33	60/--	59/--	60/--	60/--	40/38	40/39	40/40	38/37	39/29
Mdn	58/--	59/--	60/--	59/--	40/38	40/37	40/30	40/24	39/17
S+ Only Group									
#16	58/--	50/--	56/--	59/--	52/--	59/--	60/--	60/--	59/--
#36	59/--	59/--	60/--	60/--	60/--	60/--	60/--	59/--	53/--
Partial Group									
#23	51/--	60/--	59/--	60/--	40/40	40/40	40/40	40/40	40/40
#60	60/--	58/--	55/--	60/--	40/40	40/39	40/40	40/40	40/40

PHASE 1 (cont'd)					PHASE 2	
			DAY			
Subject	11	12	13	14	15	16
Discrimination Group						
#2	40/ 3	40/ 8	39/ 2	40/ 2	40/ 1	40/ 0
#7	40/40	40/40	40/40	40/31	40/20	40/ 0
#28	39/ 0	40/ 0	40/ 1	39/ 0	40/ 0	40/ 1
#33	38/15	39/ 9	38/ 0	40/ 1	34/ 0	34/ 0
Mdn	39/ 9	40/ 9	39/ 1	40/ 1	40/ 1	40/ 0
S+ Only Group						
#16	60/--	59/--	60/--	57/--	39/38	36/ 8
#36	60/--	60/--	60/--	60/--	40/14	40/ 0
Partial Group						
#23	39/39	40/40	40/40	40/40	34/36	40/11
#60	40/40	40/40	40/40	40/40	40/37	39/ 2
Median value for #16, #36, #23, and #60:					39/37	39/ 5

Experiment 4: Test Data

Subject	Total Responses to each stimulus									Responses Summed over Stimuli						
	TⓇ	TⒼ	TⓌ	NⓇ	NⒼ	NⓌ	SⓇ	SⒼ	SⓌ	Ⓡ	Ⓖ	Ⓦ	T	N	S	ALL TRIALS
Discrimination Group - first test day																
#2	32	1	24	1	0	0	28	1	23	61	2	47	57	1	52	110
#7	36	5	36	28	4	9	36	3	21	100	12	66	77	41	60	178
#28	36	23	33	5	0	0	28	6	29	69	29	62	92	5	63	160
#33	36	4	34	7	0	2	35	0	28	78	4	64	74	9	63	146
Mean	35	8	32	10	1	3	32	3	25	77	12	60	75	14	59	149
S+ Only (#16,#36) and Partial (#23, #60) Groups - first test day																
#16	36	8	24	33	0	11	36	4	13	105	12	48	68	44	53	165
#36	36	4	24	30	0	5	29	0	32	95	4	61	64	35	61	160
#23	36	1	35	36	4	29	33	5	36	105	10	100	72	69	74	215
#60	36	18	37	33	0	26	36	0	33	105	18	96	91	59	69	219
Mean	36	8	30	33	1	18	33	2	29	103	11	76	74	52	64	190
Discrimination Group - second test day																
#2	20	0	15	0	0	0	14	0	5	34	0	20	35	0	19	54
#7	24	7	24	28	4	0	33	8	16	85	19	40	55	32	57	144
#28	34	13	30	0	0	0	16	3	1	50	16	31	77	0	20	97
#33	32	10	30	6	0	1	32	0	25	70	10	56	72	7	57	136
Mean	27	7	25	9	1	0	24	3	12	60	11	37	60	10	38	108
S+ Only (#16,36) and Partial (#23,60) Groups - second test day																
#16	11	0	0	3	0	0	7	0	0	21	0	0	11	3	7	21
#36	9	0	8	1	0	0	10	1	4	20	1	12	17	1	15	33
#23	36	2	24	34	0	18	36	0	32	106	2	74	62	52	68	182
#60	37	4	37	35	0	14	36	4	36	108	8	87	78	49	76	203
Mean	23	1	17	18	0	8	22	1	18	64	3	43	42	26	41	110
Discrimination Group - both test days																
#2	52	1	39	1	0	0	42	1	28	95	2	67	92	1	71	164
#7	60	12	60	56	8	9	69	11	37	185	31	106	132	73	117	322
#28	70	36	63	5	0	0	44	9	30	119	45	93	169	5	83	257
#33	68	14	64	13	0	3	67	0	53	148	14	120	146	16	120	282
Mean	63	16	57	19	2	3	55	5	37	137	23	97	135	24	98	256
S+ Only (#16,36) and Partial (#23,60) Groups - both test days																
#16	47	8	24	36	0	11	43	4	13	126	12	48	79	47	60	186
#36	45	4	32	31	0	5	39	1	36	115	5	73	81	36	76	193
#23	72	3	59	70	4	47	69	5	68	211	12	174	134	121	142	397
#60	73	22	74	68	0	40	72	4	69	213	26	183	169	108	145	422
Mean	59	9	47	51	1	26	56	3	47	166	14	119	116	78	106	299

Experiment 4: Indices of Stimulus Control after Both Test Days

Subject	Multiplicative indices				Additive indices			
	$\frac{T}{T+N}$	$\frac{T\textcircled{W}}{T\textcircled{W}+N\textcircled{W}}$	$\frac{\textcircled{R}}{\textcircled{R}+\textcircled{G}}$	$\frac{S\textcircled{R}}{S\textcircled{R}+S\textcircled{G}}$	$T-N$	$T\textcircled{W}-N\textcircled{W}$	$\textcircled{R}-\textcircled{G}$	$S\textcircled{R}-S\textcircled{G}$
Discrimination Group								
#2	.989	1.000	.979	.977	91	39	93	41
#7	.644	.869	.856	.863	59	51	154	58
#28	.971	1.000	.726	.830	164	63	74	35
#33	.901	.955	.913	1.000	130	61	134	67
Mean	.876	.956	.869	.917	111	53	114	50
S+ Only (#16,36) and Partial (#23,60) Groups								
#16	.627	.686	.913	.915	32	13	114	39
#36	.692	.865	.958	.975	45	27	110	38
#23	.525	.557	.946	.932	13	12	199	64
#60	.610	.649	.891	.947	61	34	187	68
Mean	.613	.689	.927	.942	38	21	153	52
Mann-Whitney U:	1	0*	5-6	8	1	0*	4	7

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* $P<.03$

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