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AN EXPERIMENTAL ANALYSIS OF SOME BEHAVIOR-ENVIRONMENT INTERACTIONS IN AUTOSHAPING WITH PIGEONS

A Dissertation Presented

By

Michael Gibbs Wessells

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure Page

ABSTRACT

A comprehensive account of the effects of stimulus-reinforcer variables upon autoshaped pecking will not be forthcoming until an analysis has been made of the behavior-environment interactions that occur when stimulus-reinforcer variables are manipulated. The goal of these experiments was to analyze the retardation of autoshaped pecking that results from exposure to nondifferential light-food pairings (Gamzu and Williams, 1973) in terms of observable interactions between the environment and behavior.

The latter retardation effect might be accounted for in terms of control by concurrent stimuli. Intermittent presentations of food elicit such appetitive behaviors as visual orientations directed towards a variety of environmental features. Visual orientations may come to be controlled by those features to which orienting behaviors are differentially followed by food ingestion. In a nondifferential pairing condition, orientations to the CS are not reliably followed by food and as orientations to various stimuli are followed by food, orientations come to be controlled by concurrent stimuli. During subsequent exposure to a differential pairing condition, pecking is retarded or suppressed since both the CS and stimuli other than the CS control directed appetitive behaviors.

The purpose of Experiment I was to test the assumption that appetitive behaviors will be controlled by the stimuli

to which appetitive behaviors are most consistently followed by food. Concurrent and identical stimuli on the left (CS1) and right (CS2) keys were paired with food an equal number of times. CS1 was presented only on concurrent-CS trials and was always followed by food. CS2 was followed by food on the same concurrent trials as CS1, but CS2 also occurred alone and unpaired with food on three of four occasions. As a result, all four birds came to peck at CS1 rather than CS2 on concurrent trials. When the pairing conditions for CS1 and CS2 were reversed, CS2 came to control low rates of pecking on concurrent trials for three of four birds. Those low rates resulted from the frequent occurrence of orientations to CS1.

In Experiment II, the experiment by Gamzu and Williams (1973) was repeated with procedural modifications. Of the four birds that were exposed sequentially to nondifferential and differential pairing conditions, only one bird came to peck frequently at the CS in the two conditions. For the remaining three birds, stereotyped nonpecking behaviors were conditioned in the nondifferential pairing condition. Variants of those nonpecking behaviors came to be controlled by the CS during the differential pairing condition and during a subsequent 100%-pairing condition. These results could have been due to either control by concurrent stimuli or to the conditioning of behaviors that competed with pecking.

The purpose of Experiment III was to test whether the retardation effect could be due to response competition. If the retardation resulted from competition between nonpecking and pecking behaviors, then pecking should not be conditioned in the differential pairing procedure if only the nonpecking behaviors that were conditioned in the nondifferential procedure were followed by food. Eight birds (Groups 1 and 2) were exposed sequentially to nondifferential and differential pairing conditions, and eight birds (Groups 4 and 5) were exposed sequentially to nondifferential and 100%-pairing conditions. Half of the birds in each condition (Groups 1 and 4) received food contingent upon head-raising responses and half of the birds (Groups 2 and 5) received similar but noncontingent presentations of the CS and food. Pecking at the lighted key occurred more often for Group 1 than for Group 2 and more often for Group 1 than for Group 4. Pecking occurred infrequently in Groups 4 and 5 even though the light was always paired with food for those groups following exposure to nondifferential light-food pairings. The lighted key came to control head-raises for Group 4 but not for Group 1. The discriminative control of pecking appeared to block control of head-raising, but pecking did not appear to be engendered in a straightforward manner by light-food pairings. While the results for Groups 4 and 5 supported the response-competition account, the results for Group 1 may not have.

Altogether, the results of these experiments could be accounted for in terms of control by concurrent stimuli or response competition, but the results could not be accounted for in terms of attentional factors, learned laziness, or correlational learning.

GENERAL INTRODUCTION

In the field of learning, a distinction has frequently been made between classical respondent and operant conditioning (cf. Skinner, 1938; Mowrer, 1947; Rescorla and Solomon, 1967). Like other distinctions that have been drawn in the area of learning, the distinction between respondent and operant conditioning has been viewed at some times as a discrimination between experimental procedures and at other times as a discrimination between conditioning processes. Distinctions in terms of procedure simply describe the differences in the operations that are performed by the experimenter. Distinctions in terms of process entail the view that different experimental operations are lawfully related to different behavioral effects. Ideally, a distinction between procedures becomes a distinction between processes when it has been shown that different experimental operations are lawfully related to different behavioral effects. However, science is superstition in a very real sense, and experimenters sometimes distinguish between conditioning processes and receive immediate reinforcement from the scientific community even when different experimental operations are only fortuitously correlated with different behavioral effects. The latter point should be kept in consideration throughout the following analysis of the distinction between respondent and operant conditioning.

The original distinction as drawn by Skinner (1935,1937) was primarily procedural and was based on the observation that the occurrence of some classes of behavior (called respondents) was highly correlated with the presence of certain stimuli while other classes of behavior (called operants) bore no obvious relation to antecedent stimuli. In respondent conditioning, the experimenter arranged for the response-independent pairing of two stimuli: the conditioned stimulus (CS) and the unconditioned stimulus (UCS or reinforcer). As a result of forward pairings, the CS came to elicit a conditioned response in the sense that the occurrence of the conditioned response was highly correlated with the presence of the CS. In operant conditioning, the experimenter arranged for a response to be followed by a reinforcer. As a result of the latter operation, the conditioned response came to occur more frequently. In other words, respondent behavior was behavior that the experimenter controlled through the manipulation of stimulus-reinforcer variables while operant behavior was behavior that the experimenter controlled through the manipulation of response-reinforcer variables.

Although the original distinction between respondent and operant conditioning was based upon experimental procedures, that distinction soon came to be viewed as a discrimination between different conditioning processes. The following were among the reasons for the shift from a distinction of procedures to one of processes. First, the two conditioning procedures were originally employed to study what seemed to be very different types of behavior. Generally, behavior that was conditioned respondently involved the action of glands and smooth musculature that were innervated by the autonomic nerves. In contrast, behavior that was operantly conditioned involved the action of the skeletal musculature that was innervated by the somatic nerves. This physiologically based distinction between two types of behavior was probably appealing in that it was clearly consistent with the traditional distinction between voluntary and involuntary behavior. Second, there were several early reports (Mowrer, 1938; Skinner, 1938) of failures to operantly condition behaviors that involved the action of glands and smooth musculature. These considerations led to the view that the two conditioning procedures affected qualitatively different types of behavior (cf. Terrace, 1973 for a recent discussion). The dichotomization of respondent and operant conditioning on the basis of response dimensions was bolstered by the nature of the experimental arrangements used to study respondent and operant behavior. In respondent conditioning procedures, the subject was often highly constrained. Consequently, most skeletal behaviors could not be studied in respondent conditioning even though there were early reports that the elicitation operation resulted in the conditioning of skeletal behavior directed toward the CS (Pavlov, 1934; Zener, 1937).

Two recent developments in the field of conditioning have strongly discredited the view that qualitatively different behaviors are conditioned by the elicitation and the reinforcement operations. First, it has been shown that a number of visceral and glandular responses can be controlled by their consequences (cf. Miller, 1969). Such findings show that visceral and glandular responses cannot be classified strictly as respondent behavior. Also, such findings lend further plausibility to the view that respondent behavior is shaped by consequential factors that are inherent in the respondent conditioning procedure (cf. Prokasy, 1965 for discussion of such a view).

The second development has been the discovery of the phenomenon called autoshaping. In pigeons, the phenomenon of autoshaping is one in which response-independent pairings of a briefly lighted key with food result in the conditioning of pecks directed at the lighted key (Brown and Jenkins, 1968). Such phenomena as the autoshaping of pecking behavior in pigeons show that even a prototypical operant response like pecking cannot be classified strictly as operant behavior. Autoshaped pecking is difficult to account for in terms of adventitious reinforcement since the conditioned pecking persists even when pecking precludes the delivery of food (Williams and Williams, 1969). Although a variety of skeletal behaviors have been conditioned by performing the elicitation operation (e.g., Scholsberg, 1928; Farris, 1967; Thompson and Sturm, 1965; Creer, Hitzing and Schaeffer, 1966; DeBold, Miller and Jensen, 1965), only a profoundly anomalous phenomenon such as autoshaping could strongly break the definition of most skeletal behaviors as operant and extend the importance of stimulus-reinforcer variables to the areas of the most intensive study of operant behavior. The discovery that pecking could be elicited was of minor importance, for behavior was not originally categorized as operant or respondent on the basis of whether it could be elicited (Skinner, 1938). Indeed, Skinner (1971) observed in the 1950's that pecking could be elicited. Rather, the classification of a behavior depended upon the ability of the experimenter to identify eliciting stimuli in a particular situation. The environment in which pecking has been extensively studied was originally chosen for its apparent lack of eliciting stimuli (Ferster and Skinner, 1957). The stimulus-reinforcer factors inherent in all operant conditioning procedures were initially seen as controlling operant behavior indirectly through the response-reinforcer relation, and antecedent stimuli were said to serve a discriminative rather than an eliciting function. This view was supported by the results of early experiments (e.g., Morse and Skinner, 1958) in which the effects of stimulus-reinforcer variables upon pecking were investigated and in which rather weak control of pecking was found. Since autoshaping was found in a situation that so closely resembled the standard situation in which operant discrimination learning was studied, the possibility arose that response-dependent pairings of a stimulus and a reinforcer have the same effects as response-independent pairings of a stimulus and a reinforcer. Thus, the phenomenon of autoshaping lends plausibility to the view that the antecedents of Pavlovian conditioning phenomena are also important antecedents of many of the conditioning phenomena that are observed when operant conditioning procedures are employed (cf. Moore, 1973 and Gamzu and Schwartz, in press). In summary, autonomic responses can be controlled by consequential factors and skeletal behaviors can be controlled by stimulus-pairing factors in the prototypical situations used to study respondent and operant conditioning. When considered together, these findings lend credence to the view that respondent and operant conditioning differ primarily in terms of experimental procedure rather than in terms of conditioning process.

Empirical Aspects of Autoshaping

The interpretation of autoshaping bears centrally on the issue of whether respondent and operant conditioning are fundamentally different. Before discussing the interpretation of autoshaping, it is necessary to consider some of the basic data relevant to that phenomenon. For more complete reviews of the literature on autoshaping, see Moore (1973), Jenkins (1973) and Hearst and Jenkins (in press). Although autoshaping occurs in species other than pigeons (e.g., in squirrel monkeys (Gamzu and Schwam, 1974); in dogs (Jenkins, personal communication); in rats (Peterson, Ackil, Frommer and Hearst, 1972); in bobwhite quail (Gardner, 1969); in chickens (Wasserman, 1973); and in fish (Squier, 1969)), this discussion will be based largely on experiments with pigeons since those experiments are most relevant to the studies described below and because the autoshaping phenomenon has been studied most extensively in pigeons.

In autoshaping, repeated pairings of a brief, localized light with food results in the conditioning of light-directed behaviors (Brown and Jenkins, 1968) for most pigeons that have been studied. In the following discussion, such a brief, localized light that is controlled by the experimenter will be called the CS. Thus, the CS is defined in an operational manner, and referring to the light as the CS does not imply that the CS actually controls the behavior of the subject as the result of a conditioning process. Most often, the CS is a small, circular, transilluminated key located on eye-level relative to a White Carneaux pigeon. Although contact behaviors such as pecking have been studied most extensively in autoshaping, at least three types of CS-directed behaviors are conditioned in the autoshaping procedure. Specifically, the conditioned behaviors include orientations to, approaches toward, and pecks at the CS (Wessells, 1974). The pairings of the CS with food are necessary for the conditioning of key-directed approaches

(Wasserman, et al., 1974). Except for the CS-food pairing situation, there have been no comprehensive analyses of non-pecking, CS-directed behaviors.

Although light-food pairings appear to be necessary for the acquisition of CS-directed behaviors in the autoshaping procedure, those pairings are not a sufficient condition for the acquisition of behaviors directed towards the CS (Gamzu and Williams, 1971, 1973). Rather, a positive correlation or contingency (Rescorla, 1967) between the CS and food appears to be sufficient for the acquisition of behaviors directed towards the CS. Specifically, Gamzu and Williams showed that conditioning of the key peck did not occur when a key light was paired intermittently with food and food was presented at the same rate in the presence and the absence of the light. In the experiments by Gamzu and Williams, two conditions were studied. In the nondifferential pairing condition, the probability of food presentation was .03 for each second during the experimental session. Thus, food was presented once every 33 sec on the average. At irregular intervals averaging 30 sec, a key was illuminated for a maximum of 8.6 sec. Since food was presented once every 33 sec on the average, the CS was paired with food on every fourth CS presentation on the average. Also, food was presented once every 33 sec during the time between CS presentations (intertrial interval). Hence, food presentation was equally likely in the presence and the absence of the CS, and though the CS was sometimes paired with food, the CS was not predictive (as defined by Rescorla, 1967) of food. In the differential pairing condition, no food was presented during the intertrial interval, but the CS was sometimes paired with food as in the nondifferential pairing condition. In the two conditions, the CS-food pairings occurred with equal frequency, but only in the differential condition was the CS positively correlated with food presentation. Some birds were exposed to the nondifferential condition and then were switched to the differential condition while other birds were exposed to the two treatments in the opposite order. Gamzu and Williams found that pecks at the key were conditioned only in the differential pairing procedure. For the birds that were shifted from the nondifferential to the differential condition, only very low rates of pecking developed for most birds, and those low rates were sustained for 35 sessions. For the birds that were first exposed to the differential condition, high rates of pecking developed. When the birds that were first exposed to the differential pairing condition were shifted to the nondifferential pairing condition, the rate of pecking rapidly declined to a low level. Gamzu and Williams argued that the conditioned pecking was not maintained by adventitious reinforcement since at the time of the shift from the differential to the nondifferential condition, pecking was occurring frequently. Pecking was therefore followed by food in the initial session of the nondifferential condition and should have been maintained if that behavior were maintained by adventitious reinforcement.

Stimulus-reinforcer variables in autoshaping may be important determinants of the topography of the conditioned response (Moore, 1973; Jenkins and Moore, 1973) as well as the probability of occurrence of the conditioned response. For example, Jenkins and Moore (1973) found that when food-deprived pigeons were exposed to differential light-food pairings, pecks at the key were similar in form to pecks at the food itself. That is, the pecks were short and forceful, and the beak was often opened wide during the pecking movement. Likewise, when water-deprived pigeons were exposed to differential light-water pairings, pecks directed at the light were slower, less forceful, and accompanied by licking and swallowing movements. Also, some birds that were deprived of both food and water were exposed to pairings of one light with food and another light with water within a single experimental session. As judged by independent observers, the food-paired light tended to control the short, forceful, open-beaked pecks while the water-paired light tended to control the slower, close-beaked pecks. Therefore, the effects of the type of reinforcer in autoshaping upon the form of the conditioned response appears to depend upon associative factors rather than factors related to states of deprivation or local after-effects of ingestion of either food or water.

One of the most striking aspects of the autoshaping phenomenon is that autoshaped pecking persists even when conditions are changed so that pecking results in contingent non-reinforcement (Williams and Williams, 1969; Schwartz and Williams, 1972; Schwartz, 1973). The latter phenomenon will hereafter be referred to as negative automaintenance. Williams and Williams (1969) exposed pigeons to a negative contingency procedure in which a key was illuminated for 6 sec following intertrial intervals that averaged 30 sec in duration. If no pecks at the key occurred in the presence of the light, food was presented immediately following the offset of the light. An intratrial peck at the key terminated the light and cancelled food presentation for that trial. Under those conditions, some birds continued to peck on over half of the trials, and Schwartz (1973) reported that such pecking was not maintained by the response-dependent termination of the CS. These findings have strongly controlled the verbal behavior of students of conditioning (cf. Seligman, 1970; Bolles, 1972; Jenkins, 1973), for these findings clearly imply that the principle of reinforcement is either inadequate or incomplete even in an operant conditioning situation that has been studied very extensively. Also, these findings have facilitated the redefinition of the elicitation process from a high correlation between a class of stimuli and a class of responses to a process whereby responses are actively evoked by antecedent stimuli.

Any conclusions based upon the phenomenon of negative automaintenance are likely to be premature at this time. Hursh, Navarick and Fantino (1974) obtained negative automaintenance in only five of twelve pigeons although efforts were made to facilitate the acquisition of pecking. Of the birds that reliably pecked during the negative contingency procedure, pecking was eliminated in all but one bird by removing the relation between pecking and the offset of the CS. Specifically, pecking was eliminated both when pecking delayed the effect of the light for 2 to 5 sec and when the key remained lighted for 2 sec after food was presented. However, there is one consideration that renders uninterpretable the results of the study by Hursh et al. as well as almost all studies of negative automaintenance. In all published studies concerning negative automaintenance, the only recorded behaviors were pecks that operated the microswitch mounted behind the key upon which the CS was presented. The observations of the author and of others (Austin, Wasserman and Hearst, personal communication) show that in standard autoshaping and negative contingency procedures, it is often the case that pecks that are aimed directly at the key fall short of the key and so are not recorded by standard measuring devices. Thus, in the absence of more comprehensive measures of behavior, one cannot reject the possibility that pecking movements were sometimes being adventitiously reinforced and one cannot conclude that no key-directed pecking was occurring. Unrecorded pecks controlled by the CS are especially likely to occur when the light from the key is scattered onto nearby environmental features (Moore, 1971). The light from the key in the study by Hursh et al. apparently did scatter since those authors obtained more recorded pecks when the houselight was off and when the walls of the experimental chamber were blackened. But there was no mention of unrecorded pecking in that report.

Even if unrecorded, key-directed pecks were not occurring in the negative contingency procedure, there are other troublesome aspects of interpreting the findings of negative automaintenance. As mentioned previously, at least three key-directed behaviors are conditioned through the autoshaping procedure. One of those behaviors, approaches toward the CS, has been shown to be highly sensitive to consequential factors within the autoshaping procedure (Wessells, 1974). Specifically, when intratrial approaches toward the CS resulted in the offset of the CS and nonreinforcement, approaches toward the key were virtually eliminated even though the CS controlled visual orientations to the CS and stereotyped pacing movements. According to the casual observations of the author, orientations to and approaches toward the CS occur in a negative contingency for pecking. Now the responses of approaching toward and pecking at the CS are nonindependent in the autoshaping procedure (Wessells, 1974) in that those responses seem to belong to a single functional class of behaviors, and so reinforcement affects both behaviors simultaneously. Therefore, one may not assume that the negative contingency for pecking precludes the effects of reinforcement upon pecking behaviors, for that assumption is based upon the erroneous view that classes of behavior can be defined solely on the basis of topographical considerations. The foregoing findings pose questions that concern the structure of behavior, a topic that has been studied by ethologists for many years. One of the main questions is why autoshaped orienting and approaching can be differentiated in a negative contingency for approaching while autoshaped approaching and pecking are not differentiated in a negative contingency for pecking. Perhaps appetitive behaviors (as defined by Craig, 1918) such as the early components of the orient-approach-peck sequence in pigeons are more plastic than the later components that are more directly involved in consummation.

Another important aspect of the autoshaping phenomenon in pigeons concerns the nature of the experimental treatments that result either in the retardation of pecking or the development of low rates of pecking. If pigeons are exposed to a nondifferential pairing condition in which a CS and food are presented randomly, either no pecking (Wasserman et al., 1974) or very low rates of pecking (Gamzu and Williams, 1973) develop when the CS is subsequently paired with food in a differential manner. Also, if pigeons are exposed to explicit nonpairings of a light and food, then either the rate of acquisition of pecking or the asymptotic frequency of pecking will be retarded when the light is subsequently paired with food (Gamzu and Williams, 1973; Wasserman et al., 1974). These findings are unlike those obtained from more traditional respondent conditioning preparations (e.g., the conditioned suppression paradigm (Rescorla, 1969)). In the latter situations, the acquisition of the conditioned response is not retarded by prior exposure to random presentations of the CS and the UCS, and acquisition is not so permanently retarded by explicit nonpairings of the CS and the UCS. Additionally, in the autoshaping situation, extended presentations of food alone results in the retardation of pecking when a localized light is subsequently paired with food (Enberg, Hansen, Welker and Thomas, 1972). There may be common antecedents for the retardation of autoshaped pecking that results from exposure to the nondifferential pairing condition and the food-only condition.

Theoretical Accounts of Autoshaping

In this section, three types of theoretical approaches to the autoshaping phenomenon will be described and criticized briefly: the respondent conditioning analysis, the operant conditioning analysis, and an analysis in terms of a biological approach/withdrawal theory. These three types of analysis by no means exhaust the class of interpretations of autoshaping; they are described here so as to provide the reader with a context for the approach that underlies the studies described below.

Autoshaping as respondent conditioning. According to a respondent conditioning account of autoshaping (cf. Moore, 1971, 1973), stimulus-reinforcer variables are the primary determinants of autoshaped responding. The autoshaping and the traditional respondent conditioning situations are held to be similar not only in terms of formal procedure but also in underlying process. Just as a negative contingency for salivation is ineffective in classical salivary conditioning (Sheffield, 1965), so is a negative contingency for autoshaped pecking ineffective. The same stimulus-reinforcer contingencies that strongly affect the conditioned emotional response (Rescorla, 1969) also strongly affect autoshaped approaching and pecking. Just as the principle of stimulus substitution applies to traditional classically conditioned responses, so does it apply to autoshaped responding. Specifically, CS-UCS pairings in autoshaping are held to establish the CS-object as a surrogate for the UCS-object so that when food is the UCS, the CS will be pecked at as if it were food (Jenkins and Moore, 1973). The following statements by Moore (1973) illustrate the potential implications of the view that autoshaped responses are governed by the process of Pavlovian conditioning:

> It is quite possible that the success of operant shaping techniques in this situation is due to stimulus-reinforcement, rather than response-reinforcement, pairings. Note that the reinforcer is at first given when the pigeon is facing the key; stimuli in that area are thus paired with food, and should begin to attract the animal . . . Through successive approximations, the Pavlovian association would be further strengthened, and the set of conditioned stimuli concurrently narrowed and finally limited to the key and immediately surrounding cues. (p. 176)
>
> In every case both the acquisition and maintenance of the response follow at once from Pavlovian principles. In every case, the Pavlovian process accounts for both the form and direction of the learned behavior. The operant principle, by contrast, is in some cases patently irrelevant, and in all cases unnecessary. For these reasons, it seems parsimonious to interpret the pigeon's simple instrumental peck as a Pavlovian conditioned response. (p. 177)

Thus, the phenomena of autoshaping may set the occasion for the explanation of such fundamentals of operant conditioning as shaping and behavioral contrast (Gamzu and Schwartz, 1973).

The major problems with the foregoing account of auto-shaped responses in terms of respondent conditioning principles is the lack of agreement as to what are the principles of respondent conditioning. For example, the principle of stimulus-substitution has been used to account for the topographical similarity between the conditioned response and the unconditioned response in autoshaping. However, the principle of stimulus-substitution is hardly a general principle within the traditional domain of respondent conditioning (cf. Schneiderman, 1973) since there are numerous apparent exceptions to that principle. There is currently no powerful principle that allows one to predict the form of a conditioned respondent. The latter problem is one of many problems of behavioral structure that are only beginning to receive experimental attention (Schwartz, 1974).

Another problem with the respondent conditioning analysis of autoshaping is that the acquisition and maintenance of conditioned respondents can often be accounted for in terms of the principles of operant conditioning. For example, it has been suggested (e.g., Perkins, 1968) that a Pavlovian conditioned response functions to prepare the animal for the delivery of the unconditioned stimulus. It should be noted that the view of respondent conditioning as involving the acquisition of preparatory responses (as well as other analyses that involve the notion of response-shaping) essentially asserts that a Pavlovian conditioned response is controlled by the events that follow it, as in operant conditioning. The Pavlovian conditioned response might be shaped from the originally diffuse orienting reflex (Sokolov, 1963) that occurs in most conditioning situations. No comprehensive analysis has yet been made of the behavioral antecedents of responses such as salivation, and so the strongest type of response-shaping analysis of respondent conditioning remains untested.

Autoshaping as operant conditioning. An account of autoshaping in terms of traditional operant conditioning principles might proceed in several ways, but only the most persuasive forms of such an account will be considered here (cf. Jenkins, 1973 for a discussion of other analyses of autoshaping in terms of operant conditioning). One might begin by noting that when a pigeon's key-peck is shaped through successive approximations, visual orientations to and approaches toward the key are selectively reinforced. Consequently, there is an increased probability that pecks at the key will occur. Once pecks at the key are occurring reliably, the entire orient-approach-peck sequence is followed by food and so will occur more frequently. This sequence might be maintained as a chain of responses that is similar to other chains of operant behavior (Skinner, 1938). Just as orientations to and approaches toward the key are followed by food when pecking is explicitly shaped by the experimenter, so orientations to and approaches toward the key are followed by food in the autoshaping procedure prior to the acquisition of pecking. One could note that general investigatory and orienting behaviors occur frequently in a situation where food is delivered intermittently and independently of behavior (Skinner, 1948; Staddon and Simmelhag, 1970; Wessells, 1974). Thus, orienting behaviors would be frequently occurring and if those behaviors were directed to a wide variety of environmental features, then only orientations toward the CS would be differentially followed by food. Accordingly, only the CS would acquire control over orientations, and the repeated occurrence of orientations to a certain stimulus would eventually result in the shaping of pecking behaviors. Such an account could explain the effects of various types of stimulus-reinforcer factors upon the frequency of autoshaped pecking.

Several aspects of autoshaping cannot be explained even by this strong form of operant conditioning account. First, such an account cannot explain why autoshaped pecking persists in a negative contingency for pecking. In that procedure, approaches toward the CS are often followed by food while approach-peck sequences are never followed by food. Therefore, approaching and pecking should be differentiated as the result of the differential reinforcement contingencies inherent in that negative contingency procedure. However, approaching and pecking are not differentiated in a negative contingency for pecking while orienting and approaching are differentiated in a negative contingency for approaching (Wessells, 1974). Another problem for the traditional operant conditioning account of autoshaping is that it provides only weak predictions concerning the form of the conditioned response. For example, Skinner (1938) held that the topography of an operant response depended upon both experimenter-defined and implicit contingencies of reinforcement. Implicit reinforcement contingencies insure the automatic reinforcement of the easiest or least harmful form of response. Recent evidence (Bolles, 1970; Moore, 1973) indicates that the form of a conditioned response is not purely arbitrary but is often related to certain species-typical behaviors. Indeed, an important type of implicit reinforcement contingency may be the opportunity for the expression of species-typical behaviors. The antecedents of the form of species-typical behaviors may be clarified by consideration of the function of those behaviors. A third problem for the operant conditioning account is an account of why the occurrence of visual orientations to the CS in contiguity with food presentation results in the shaping of approaching and pecking behaviors rather than some other forms of behavior. Indeed, the acquisition of any CS-directed behaviors is surprising since during the acquisition of autoshaped pecking, CS-directed behaviors are seldom followed immediately by the reinforcer (Wessells, 1974).

An analysis of autoshaping in terms of a biological approach/withdrawal theory.

No attempt has yet been made to account for autoshaping (or any conditioned respondent behavior) in terms of a biological approach-withdrawal theory like that described by Glickman and Schiff (1967). The following account is based on the author's extensions of the theory proposed by Glickman and Schiff. The theory is described for the purpose of illustrating how the study of adaptive, species-typical behavior might be integrated with the study of autoshaping and other conditioning phenomena.

The theory of Glickman and Schiff is based upon the dichotomization of vertebrate behavior into species-typical sequences of approach and withdrawal (as defined by Schneirla, 1959). Basically, approach sequences consist of responses that bring the organism into contact with stimuli that have acted to enhance the survival of previous members of the species. Withdrawal sequences consist of responses that remove the organism from stimuli that have threatened the survival of the species. Reinforcement is held to consist of the neural facilitation of species-typical motor patterns. As the result of natural selection, the facilitation of the neural pathways underlying approach behaviors is presumed to be positively reinforcing while the activation of pathways underlying withdrawal behaviors is held to be aversive. This theory was founded on several types of observations. First, species-typical behaviors can be elicited by stimulating electrically certain brain sites. Secondly, brain stimulation that elicits approach behaviors can serve as a positive reinforcer for other operant behavior. Finally, the opportunity to emit species-typical approach behaviors is often positively reinforcing (cf. Glickman, 1973 for further discussion of these points). It should be noted that reinforcement is defined in terms of the activation of neural mechanisms rather than the actual occurrence of a highly probable species-typical behavior. Thus, reinforcement may occur even in the absence of observable responding controlled by a reinforcing stimulus such as brain stimulation.

In the extension of the theory of Glickman and Schiff, one might assume that differential stimulus-reinforcer pairings result in the establishment of the CS as an activator of some of the same neural pathways that are activated by the UCS. This assumption has several interesting consequences. For example, in appetitive conditioning, the conditioned response and the unconditioned response would be predicted to be similar in topography. The precise form of the conditioned response would depend in part upon the nature of the CS since some types of CS provide the opportunity for a more complete expression of species-typical behaviors than others. Interestingly, the emission of the conditioned response would be predicted to be reinforcing, and the magnitude of the reinforcement would depend upon the extent to which the CS-object allowed for the expression of the species-typical behavior. Additionally, a type of UCS may control more than a single motor pattern, and the motor pattern that occurs would be determined by the properties of the UCS-object. According to this account, stimulus substitution may be said to occur when the CS controls some responses that are members of the same functional (rather than topographical) class of responses that is controlled by the

UCS. Thus, apparent exceptions to the stimulus-substitution principle in autoshaping (e.g., Wasserman, 1973) may not in fact be inconsistent with that principle. Likewise, since stimulus-reinforcer pairings occur in all operant conditioning situations (although the stimulus is not always experimenter-defined), the reinforced response should be topographically similar to the response controlled by the reinforcing stimulus. Indeed, Wolin (1948) has reported that in a free-operant situation, the topography of the pecking response of pigeons is dependent upon whether food or water is the reinforcer, as in autoshaping. Generally, an operant response would not be expected to be arbitrary in form but would rather be similar in form to the class of species-typical behaviors that are elicited in a particular situation. Operant conditioning would not be expected to occur in situations in which the operant response is incompatible with the species-typical behaviors that are controlled by stimuli in the experimental setting. In fact, operant conditioning occurs with difficulty in the latter types of situation (cf. Breland and Breland, 1961; Bolles, 1970; Schwartz, 1974). For example, when raccoons are reinforced with food for inserting poker chips into a slot, species-typical washing behaviors come to interfere with the operant response of inserting the chips (Breland and Breland, 1961). This finding could be predicted by the approach-withdrawal theory since the poker chips are paired with food and provide an optimal opportunity for the washing behaviors that are elicited by intermittent feeding. Under the circumstances, the washing behaviors may be highly reinforcing (on a momentary basis, perhaps even more so than eating) and so they compete with the incompatible response of insertion. A similar account could be given for the phenomenon of negative automaintenance.

The biological approach-withdrawal theory will be neither elaborated further nor criticized here since no serious attempts have been made to interpret autoshaping within such terms. Such attempts should be forthcoming, for they could help to integrate the ethological and the experimental approaches to the study of animal behavior. That integration could elucidate the nature of conditioning and help to ascertain the adaptive significance of conditioning phenomena.

One-process theories of conditioning. Having considered some of the basic data and theories relevant to the autoshaping phenomenon, the implications of the autoshaping phenomenon may now be considered. One clear implication of the autoshaping phenomenon is that there is currently a profound lack of understanding of the behavioral repertoire that the pigeon brings to the conditioning situation. Consequently, there is currently a poor understanding of some basic aspects of conditioning. As a first step in exploring the implications of autoshaping, the question of whether there are two types of conditioning process must be reconsidered.

The distinction between respondent and operant conditioning on the basis of response dimensions is made tenuous by the phenomena of autoshaping and the sensitivity of visceral and glandular responses to response-reinforcer variables. However, one might distinguish between respondent and operant conditioning on a basis other than that of response dimensions. For example, a given class of topographically similar responses could be sometimes controlled solely by stimulus-reinforcer variables and at other times by response-reinforcer variables. One could contend (cf. Moore, 1971; Gamzu and Schwartz, in press; Gamzu and Schwam, 1974) that in respondent conditioning, the class of conditioned responses is not only controlled by stimulus-reinforcer variables but is also insensitive to response-reinforcer variables in the situations in which the elicitation operation is performed. According to the latter view, a critical test for determining whether a class of responses is a respondent or an operant would be to ascertain the effect of some type of negative contingency between the conditioned response and the reinforcing stimulus.

There are sevral reasons for rejecting the latter test as a critical test for distinguishing between respondent and operant conditioning. First, in standard respondent conditioning situations, there have been no comprehensive analyses of the behaviors that are conditioned prior to the occurrence of the experimentally defined, conditioned response. Consequently, little is known of the composition and the structure of response classes in respondent conditioning. It may be that, as in autoshaping, behaviors that are nonindependent with respect to the measured conditioned response are conditioned prior to the measured response. Until the class of conditioned responses has been analyzed fully, one cannot ascertain the effects of a negative contingency procedure upon the class of conditioned responses. Secondly, when one contends that a negative contingency procedure is a valid assay for distinguishing respondents from operants, one implicitly assumes that any observed ineffectiveness of response-reinforcer variables results from the direct, eliciting effects of stimulus-reinforcer variables. In fact, response-reinforcer variables may sometimes be ineffective with respect to such responses as salivation even in the absence of obvious eliciting stimuli (Miller, 1969). Thus, even if the elicitation operation results in the conditioning of a salivatory response and that response is insensitive to a negative contingency procedure (as in Sheffield, 1965), one may not conclude that stimulus-reinforcer factors were more powerful determinants of the conditioned response than were response-reinforcer factors.

Finally, one might attempt to distinguish between respondents and operants on the basis of whether a response is initially controlled in the experimental situation by stimulus-reinforcer pairings that are programmed to occur independently of responding. Presumably, one could assess whether adventitious reinforcement mediated the effects of the stimulus-reinforcer pairings by exposing each subject sequentially to differential and nondifferential pairing conditions (as in Gamzu and Williams, 1971). If the responses that were conditioned by differential pairings are maintained when the UCS is presented with equal frequency in the presence and the absence of the CS, then the response could not be said to be respondent in nature. This basis for distinguishing between respondents and operants is made tenuous by the consideration that the effects of stimulus-reinforcer pairings may be independent of whether the pairings are response-dependent.

The results of a recent study by Jenkins (1973) illustrate the latter point. Jenkins trained two groups of naive pigeons to interrupt an overhead photobeam by a head-raising response. The response was shaped through the method of successive approximations, and responses were followed by food presentation. Interestingly, the topography of the response soon shifted from a lifting of the head to pecking movements. Next, the response was reinforced in a standard, discrete-trials procedure according to an FI 8-sec schedule of reinforcement. Following an average intertrial interval of 30 sec, a tone was presented for 8 sec, and the first response at the end of 8 sec was followed by food. Then the procedure was changed so that a response could be reinforced only on every fourth trial on the average. That is, a response in the presence of the tone was reinforced once every 32 sec on the average. When the intratrial response rates were stable, the birds were divided into two groups. For both groups, food was delivered independently of responding. For group 1, the tone was differentially paired with food with the same frequency as before. For group 2, food was paired with the tone as frequently as before, but food was also presented at the same rate (once every 32 sec on the average) in the absence of the tone. Thus, group 1 received differential tone-food pairings while group 2 received nondifferential tone-food pairings. The results were that the rate of responding for group 1 declined slightly while responding for group 2 virtually ceased. In a subsequent phase, the groups were reversed so that group 1 received nondifferential tone-food pairings and group 2 received differential tone-food pairings. As before, the differential pairings resulted in the control of a moderate response rate by the tone while in the nondifferential condition, the tone controlled a zero rate of responding. Thus, as the result of response-dependent tone-food pairings, the tone came to elicit responding even when the tone-food pairings occurred independently of responses and even when responding had declined to a zero level. Jenkins also showed that no responding was conditioned when naive pigeons were exposed to differential, response-independent pairings of tone and food.

In traditional terminology, the tone in Jenkins' experiment was originally a discriminative stimulus rather than an eliciting stimulus. Yet after the tone had become a discriminative stimulus, it had acquired eliciting properties also. It seems clear that at least for some behaviors, the elicitation and reinforcement operations result in qualitatively similar types of stimulus control. Clearly, it is an oversimplification to distinguish between operants and respondents on the basis of whether differential stimulus-reinforcer pairings are initially sufficient to engender responding. Indeed, it may be that such "classically conditioned" responses as autoshaped pecking have the same ontogenetic antecedents as the measured responses in the experiment by Jenkins. In the future, a more general study of the ontogeny of behavior should help to clarify the necessary and sufficient conditions for the control of behavior by stimulus-reinforcer and response-reinforcer variables.

In summary, there are currently no unambiguous criteria for distinguishing between respondent and operant conditioning on the level of process. Respondents and operants can be distinguished neither on the basis of response dimensions nor on the basis of sensitivity to consequential factors. Respondent and operant conditioning processes cannot be distinguished on the basis of such phenomena as response-shaping or the topographical similarity between the conditioned response and that controlled by the reinforcing stimulus. The distinction between respondent and operant conditioning in terms of process cannot be maintained on the basis of whether the conditioned response is controlled by stimulus-reinforcer or response-reinforcer variables. At this time, it seems possible to account for many basic operant phenomena in terms of principles of respondent conditioning and conversely, it seems possible to account for many basic respondent phenomena in terms of principles of operant conditioning. These considerations seem to lead inevitably to the conslusion that operant and respondent conditioning can currently be distinguished only in terms of experimental procedures rather than in terms of process.

Having concluded that respondent and operant conditioning are distinguished only in terms of experimental operations, there arises an immediate question as to the nature of the unitary conditioning process. Given the history of many students of learning, it is not surprising to find that the latter question has been defined as one of whether the most basic learning process is respondent or operant conditioning. Moore (1971, 1973), for example, has postulated that Pavlovian conditioning is the one basic process that underlies the basic phenomena of respondent and operant conditioning. Moore's approach becomes convincing only if one is willing to postulate extensively concerning response-inferred stimuli, and such postulations make the approach difficult to test. Furthermore, as noted earlier, one could argue convincingly that operant conditioning is the most basic process. However, the latter type of account is plausible only if substantial modifications of basic operant principles are made. Many of those modifications would have to concern the problem of how experimentally programmed events interact with what the organism brings to the situation. That either respondent or operant conditioning could be viewed as the more basic conditioning process is indicative of our current lack of understanding of conditioning. To argue whether respondent or operant conditioning is more basic is likely to be a barren endeavor at this time, and such argumentation might only serve to perpetuate the dichotomy between respondent and operant conditioning.

An Analysis of Some Effects of Stimulus-Reinforcer Variables

It seems clear that there are fundamental gaps in current conceptions of conditioning and that the most significant gaps are in those areas related to problems of the structure of behavior. In the following discussion, it will be assumed that there is a single conditioning process. The nature of the conditioning process might be ascertained by the study of the behavior-environment interactions that occur in the conditioning situation and by the definition of the units of behavior and the relationship between those units for the members of the species under investigation. In the following discussion, an attempt will be made to analyze aspects of the phenomenon of autoshaping in terms of observable interactions between behavior and environment.

It is possible to speak of the antecedents of autoshaped behaviors solely in terms of the stimulus-reinforcer variables that are manipulated by the experimenter. However, if our goal is to formulate comprehensive accounts of the behavior of our experimental subjects, then our goal is to bring our own verbal behavior under control of the same events that control the behavior of our subjects. When one speaks of the effects of stimulus-reinforcer variables, he is describing the variables that he has manipulated or observed, but he has not described the behavior-environment interactions that may be controlling the behavior of his experimental subject. In traditional, respondent conditioning preparations, the experimental subject is often highly constrained and exposed to diffuse stimuli. Consequently, only certain types of behavior-environment interactions are permitted to occur, and the experimenter is necessarily left with only stimulus-reinforcer variables to speak of prior to the acquisition of the measured conditioned response. In contrast, the autoshaping situation is characterized by localized stimulation, relatively few experimental constraints upon the behavior of the subject, and the occurrence of a variety of exploratory and appetitive behaviors prior to the conditioning of the pecking behavior. When one manipulates stimulus-reinforcer variables in the autoshaping situation, one also arranges for many observable interactions between environment and behavior, and those interactions have not been studied in depth. Until those interactions have been studied comprehensively, it seems premature to speak of the antecedents of autoshaped behaviors solely in terms of stimulus-reinforcer variables.

On a deeper level, the study of autoshaping in pigeons shows that just as there may be no difference in process between respondent and operant conditioning, so there may be no difference in the types of behavior-environment interactions that occur when one manipulates stimulus-reinforcer or response-reinforcer variables. For example, when one consistently pairs a brief, localized light with food, orienting behaviors directed toward the CS are first conditioned. Prior to the acquisition of autoshaped pecking, both orientations to and approaches toward the CS often occur and are followed by food. Finally, the entire orient-approach-peck sequence is followed by food. These same behavior-environment interactions are those that are explicitly arranged by the experimenter when the pecking response is shaped through successive approximations.

Therefore, it seems gratuitous to speak of autoshaped behaviors as being controlled by stimulus-reinforcer factors while experimenter-shaped behaviors are spoken of as being controlled by response-reinforcer factors. Furthermore, it seems gratuitous to argue over which set of factors is the more critical determinant of autoshaped behaviors, for such a question is merely an operationalized variant of the problem of whether respondent or operant conditioning is more basic. The basic strategy for what follows is to analyze behavior-environment interactions in autoshaping. In order to avoid basing the analysis upon unobservable, response-inferred stimuli, observable response-reinforcer variables will be stressed, but the present approach could by no means be encompassed by traditional conceptions of operant conditioning.

As noted above, when a lighted key is differentially paired with food, the light comes to control pecks at the key; but when a lighted key is paired with food in a nondifferential manner, acquisition of pecks at the key does not occur (Gamzu and Williams, 1971, 1972). Also, when pigeons are shifted from a differential pairing procedure to a nondifferential pairing procedure, the rate of CS-directed pecking falls to a level near zero. The foregoing findings were interpreted by Gamzu and Williams as showing that the conditioned pecking was controlled directly by stimulus-reinforcer factors and that the conditioned pecking was classically conditioned. However, those findings may not necessitate an account in terms of stimulus-reinforcer factors, and it may be possible to account for the findings of Gamzu et al. in terms of observable interactions between the environment and behavior. The following is one version of the latter type of account and is based upon extensive observations made by the author.

When food is intermittently delivered to pigeons in a noncontingent fashion, a variety of appetitive behaviors are elicited and occur frequently. Among the observed appetitive behaviors are monocular and binocular visual orientations to, approaches toward, and pecks at various aspects of the environment (such as screw heads, the houselight, and the speaker through which white noise was delivered). Those appetitive behaviors may be highly probable in free-feeding situations as a result of prior exposure to situations in which the probability of successful food ingestion is relatively high given the recent occurrence of food ingestion in a particular setting. Once the appetitive behaviors have been elicited, those behaviors can be followed by food and can be reinforced adventitiously (Stadden and Simmelhag, 1971; Skinner, 1948). Additionally, nonappetitive behaviors such as pacing and head-bobbing may be conditioned along with the appetitive behaviors. The major point is that experimentally programmed light-food pairings are not necessary for the conditioning of directed behaviors that are topographically similar to those that are conditioned in the autoshaping procedure. The conditioning of those behaviors in the autoshaping experiment may involve the redirection of frequently occurring appetitive behaviors (cf. Staddon and Simmelhag, 1971 for a discussion of conditioning as a selection process).

Now consider the behavior-environment interactions that might occur in the conditions arranged by Gamzu and Williams. At the time of magazine training, appetitive behaviors such as visual orientations are directed toward a wide variety of features in the experimental setting. When a localized light is differentially paired with food, orientations to the light are more likely to be differentially followed by food than will orientations to other aspects of the environment. Just as the appetitive behaviors in the species-typical setting are directed toward those stimuli (for example, the sight of grain) to which orientations are reliably followed by food ingestion, so the appetitive behaviors in the experimental setting come to be controlled by those features for which orienting behaviors are differentially followed by food ingestion. Just as in the species-typical setting, when orientations to the light are reliably followed by food, the light comes to control the complete sequence of orienting, approaching and pecking behaviors. But when food is presented in the experimental setting as frequently between trials as during the CS, visual orientations to the CS are not followed differentially by food while orientations to other environmental features can be followed differentially by food, and, in this manner, appetitive behaviors may be directed away from the CS. Indeed, observations made by the author of pigeons in a nondifferential pairing condition like that of Gamzu et al. are consistent with the preceding account. Specifically, the behavior of pigeons in a nondifferential pairing condition most often consists of stereotyped pacing movements along the front panel. During the emission of those pacing movements, the head of the bird is moved along the front panel in a stereotyped manner and the bird's beak is pointed toward a small number of positions along the front panel. Thus, binocular orientations become controlled by certain aspects of the environment, and those orientations are accompanied by the type of behaviors that were first described by Skinner (1948) as "superstitious."

To test the foregoing account of the effects of differential and nondifferential light-food pairings upon autoshaped key pecking, one might best begin by examining the effects of exposure to nondifferential pairing conditions. A nondifferential pairing procedure provides optimal conditions for appetitive and nonappetitive behaviors to come under stimulus control of environmental features other than the lighted key. Following exposure to a nondifferential pairing condition, appetitive and nonappetitive behaviors should continue to be controlled by stimuli other than the key even when the lighted key is differentially paired with food. Thus, if a pigeon were exposed first to a nondifferential pairing condition and then shifted to a differential pairing condition, then either no key pecking or very little key pecking should be acquired in the differential pairing condition. In fact, differential light-food pairings result in very little key pecking following extensive exposure to a nondifferential pairing condition (Gamzu and Williams, 1971, 1973).

To illustrate how the retardation of pecking reported by Gamzu and Williams might be accounted for in terms of interactions between the environment and behavior, consider the following hypothetical example. S1, S2 and S3 are sometimes followed by food, although far less often than in the nondifferential pairing condition. The decreased frequency of food presentation is presumed to result in increases in the topographical variability (both between and within classes) of both appetitive and nonappetitive behaviors and so orientations start to occur not only to S1, S2 and S3 but also to many other stimuli such as the lighted key. In the differential pairing condition, orientations to the lighted key are more likely to be followed by food than are orientations to S1, S2 and S3, and so the lighted key may come to control appetitive behaviors. However, if the appetitive behaviors had been reinforced extensively in the presence of S1, S2, and S3, then the stimulus control of appetitive behavior would most likely be shared by the lighted key, S1, S2, and S3. Even though the lighted key is the experimenter-defined CS in the preceding situation, that situation might be best viewed as one in which behavior is controlled by concurrent stimuli.

The purpose of the experiments described below is to analyze in terms of behavior-environment interactions the retarding effect of nondifferential light-food pairings upon autoshaped pecking. An analysis in terms of observable behavior-environment interactions may help to clarify the factors that actually affect the behavior of the subject when stimulus-reinforcer variables are manipulated independently of what the subject does.

EXPERIMENT I

If the retardation of autoshaped pecking that results from nondifferential light-food pairings is to be accounted for in terms of control by concurrent stimuli, then one necessarily assumes that when two food-paired stimuli are simultaneously present, appetitive behaviors like orienting and pecking will be controlled by the stimulus to which orientation and pecks are most consistently followed by food. The purpose of this experiment is to test that assumption by arranging for two identical stimuli to always precede food presentation. One stimulus (CS1) will always be followed by food while the other stimulus (CS2) will be followed by food only 25 percent of the time. Thus, CS1 together with CS2 always precede food presentation, and CS2 is also presented alone on three of four occasions and is not followed by food. Since behaviors directed toward CS1 are always followed by food while behaviors directed toward CS2 are only sometimes followed by food, orienting, approaching, and pecking behaviors should come to be controlled by CS1 when both CS1 and CS2 are present.

Method

Subjects. Four experimentally naive, White Carneaux pigeons maintained at 80% of their free-feeding weight served in the study.

Apparatus. One standard Lehigh Valley experimental chamber was controlled by conventional electro-mechanical equipment in a nearby room. Extraneous noises were masked by white noise and the sound of the ventilating fan of the chamber. The white noise (85 dB) was presented through a speaker mounted on the control panel of the chamber. The chamber was constantly illuminated by a houselight fixed on the middle of the control panel and about 2.5 cm from the ceiling. The houselight was a GE 44 bulb operated at 6V dc, and the bulb was partially covered by a metal housing so that light was deflected towards the ceiling. Mixed grains could be presented in a standard food hopper.

Stimuli could be presented on either of two keys by means of in-line display cells (Industrial Electronics

Engineers) mounted behind the keys. The light sources for the stimuli projected on the keys were GE 44 bulbs operated by 6V dc.

The observation window of the chamber was covered by a sheet of metal and all observations were made through a 10 cm x 10 cm window in the rear wall of the chamber. The window was covered by a sheet of clear plastic. Just outside the window and placed in a constant position was a Sony video camera (AVC-3200). The camera was connected to an AV-3650 recorder and CVM-9204 monitor located in a nearby room. Use of the video system made it possible to view each session as it occurred and to record any especially interesting behavior for further observation.

Procedure. Each bird was magazine trained in the following way. On day 1, the subject was placed in the chamber for 20 minutes. On that day, grain was continuously available and the chamber was illuminated only by the feeder light. On day 2, food was presented continuously and as in all sessions thereafter, the chamber was constantly illuminated by the houselight. On day 3, food was presented independently of behavior at variable intervals that were 15 seconds in mean duration (this schedule is called a variable time 15-second schedule (VT 15-sec)), and the duration of food presentation was progressively decreased to 4 sec, at which point it remained constant. On day 4, food was presented 40 times according to a VT 60-sec schedule. Both keys remained darkened throughout the four days of magazine training.

On day 5, Phase 1 of the experiment began. Each session during Phase 1 consisted of 80 trials presented according to a VT 30-sec schedule. Two types of trial occurred within each session. On single-CS trials, the right key was transilluminated with white light (CS2) for 6 sec and was not followed by food. On concurrent-CS trials, both the left and right keys were transilluminated with white light for 6 sec and were always followed immediately by food. Both the lighted left key (CS1) and CS2 were virtually identical in size and brightness and so CS1 and CS2 were distinguished primarily by position. In each session of 80 trials, 60 single-CS and 20 concurrent-CS trials occurred in an irregular order with the restriction that no more than 8 single-CS trials occur in succession. The left key light was paired with food 100% of the time and the right key light was paired with food only 25% of the time. On the average, every fourth trial was a concurrent-CS trial and so concurrent-CS trials occurred once every 120 sec on the average. During the intertrial interval both keys were unilluminated.

Phase 1 was as described for all birds except bird 156. For bird 156 the first two sessions of Phase 1 consisted of 40 trials in which a single CS was presented for 6 sec and was followed immediately by food. On half of the trials, CS1 was presented and paired with food, and on half the trials, CS2 was presented and paired with food. CS1 and CS2 were presented in an irregular order with the restriction that either CS could occur no more than three times in succession. The purpose of these two sessions was to insure that directed behaviors were controlled by both CS1 and CS2 before exposure to the standard procedure of Phase 1. If pecking were initially controlled by both CSs, then one could measure changes in response rate to each CS during exposure to the standard procedure of Phase 1. Only bird 156 received special treatment since it was later discovered that both CSs acquired control over pecking during the initial sessions of the standard Phase 1 procedure.

Throughout each session, the behavior of the birds had no effect upon the programmed events, but pecks at the keys that closed the micro-switch behind the key were recorded. When the rates of pecking for a particular subject appeared stable for three successive sessions, Phase 2 of the experiment was begun for that bird. In Phase 2, the pairing conditions for the two CSs were reversed so that the right key was paired with food 100% of the time and left key was paired with food only 25% of the time.

Results And Discussion

For each bird in Phase 1, pecking came to be controlled by both CS1 (100% pairing) and CS2 (25% pairing). Figure 1 shows for each bird the mean response rate controlled by

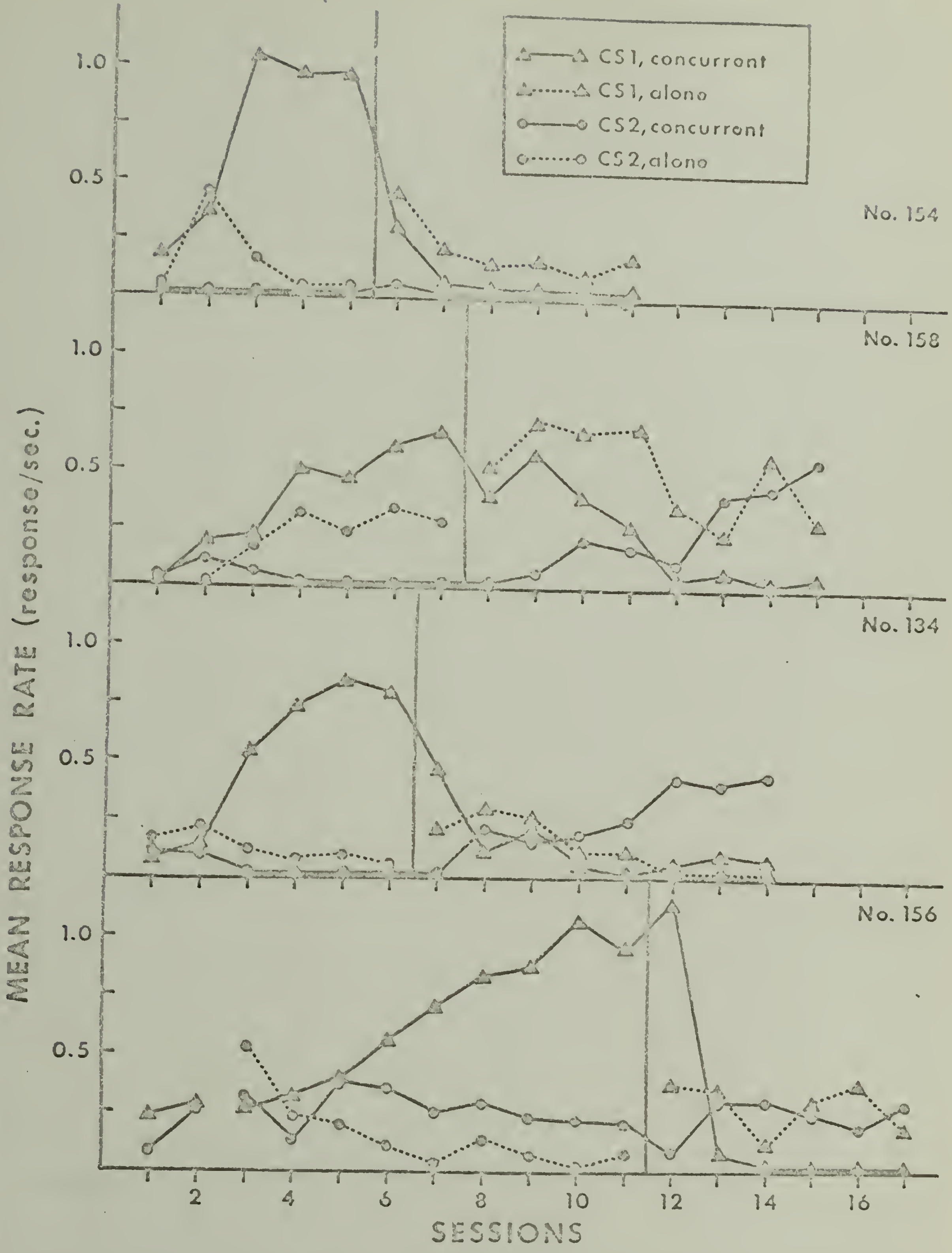

Figure 1. The mean rate of pecking at CS1 (left key) and CS2 (right key) during concurrent-CS and single-CS trials. Each graph shows data for a single subject. The solid vertical line separates the data from Phases 1 and 2 for each bird.

CS1 (left key) and CS2 (right key) during both concurrent-CS and single-CS trials. In the early sessions of Phase 1, all birds except bird 154 pecked at both CS1 and CS2 on concurrent-CS trials. Bird 154 was similar to the other birds in that he oriented frequently to both CSs on the concurrent-CS trials even before the acquisition of pecking had occurred. All birds pecked at CS2 on single-CS trials even in the initial sessions of Phase 1.

In the latter sessions of Phase 1, pecking was strongly controlled by CS1 but not by CS2 on concurrent-CS trials. Indeed, all birds except bird 156 stopped pecking CS2 entirely when both CSs were presented together. Bird 156 pecked at CS1 almost four times as often as at CS2, but on some concurrent trials, bird 156 at first pecked at CS2 and then switched over to CS1. Bird 156 rarely pecked only at CS2 when CS1 was also present. The control of pecking by CS1 clearly did not result from a failure of pecks at CS2 to be followed by food since three of four birds pecked at both CSs at similar rates during the initial concurrent-CS trials. Also, on some early concurrent trials, pecks occurred only to CS2 and were followed by food. Interestingly, pecking continued to be controlled by CS2 on single-CS trials throughout Phase 1 for all birds except bird 154. Birds 158 and 134 continued to peck at CS2 when CS2 occurred alone even though those birds never pecked at CS2 when both the CSs were present. These results show that the birds did not simply stop attending to CS2.

In Phase 2, the light-food pairing conditions were reversed such that CS2 was always paired with food while CS1 was paired with food only 25% of the time. Consequently, for three of four birds, CS2 acquired a high degree of control over pecking on concurrent-CS trials and CS1 came to control infrequent or no pecking on concurrent-CS trials. CS2 acquired control over pecking on concurrent-CS trials even though pecking had been highly controlled by CS1 at the start of Phase 2. Despite the fact that pecking at CS1 had initially occurred at a high rate and was followed by food, pecking came to be controlled by CS2 when both CSs were present. During the acquisition of stimulus control by CS2, many responses occurred to CS1 on single-CS trials and were therefore not followed by food. As pecking at CS1 on concurrent trials decreased in frequency, all birds began to orient frequently toward both CSs on concurrent trials. Just after the transition to Phase 2, all birds entirely stopped pecking during several concurrent trials. On those occasions, the birds first oriented towards CS1 and then towards CS2 and then back to CS1, etc. For all birds except bird 154, CS2 acquired control over pecking soon after the period during which the double orientations occurred on concurrent trials. However, bird 154 continued to orient towards both CSs on concurrent trials even though no pecking occurred. Throughout the concurrent trials, bird

154 stood between the two keys and pointed his beak directly towards CS2 and then towards CS1, etc.

In Phase 2, a relatively low rate of pecking was controlled by CS1 on single-CS trials for all birds except bird 134. Bird 154 continued to peck at CS1 when it was presented alone even though he never pecked at either CS when both were present. Since most birds continued to peck at CS1, the birds did not simply stop attending to CS1 during Phase 2.

One interesting result of the experiment was quite unexpected even though the result is consistent with the assumption being tested. For all birds except bird 158, the rate of pecking controlled by CS2 on concurrent trials in Phase 2 was substantially lower than the rate than had been controlled by CS1 during Phase 1. The low rates of pecking controlled by CS2 did not result from some peculiar characteristic of CS2 since in pilot studies by the author it was observed that high rates of pecking at CS2 occurred when CS2 was always paired with food from the start of the experiment. Also, since CS1 and CS2 were highly similar in appearance, no differences in response rate would be expected to occur on the basis of physical differences between the stimuli. The low rate of pecking at CS2 resulted from the fact that the birds continued to orient frequently towards CS1 on concurrent trials in Phase 2. For example, on concurrent trials, pecks at CS2 were often followed by orientations to and approaches towards CS1 which were in turn followed by orientations to, approaches towards and pecks at CS2. Occasionally, an orientation towards CS1 was the behavior that was followed most closely by food on concurrent trials. Thus, both CSs clearly controlled behavior in the concurrent trials of Phase 2 even though pecking was controlled almost solely by CS2. The failure of CS2 to acquire control of a high rate of pecking in Phase 2 was apparently not due to a blocking effect of CS1. Rather, the control of CS-directed behavior was shared by the two CSs.

The results of this experiment support the assumption that when two food-paired stimuli are simultaneously present, appetitive behaviors such as pecking are controlled mainly by the stimulus in the presence of which those behaviors are most consistently followed by food. Furthermore, these results show that after one stimulus, S1, has acquired control over behavior, when two stimuli, S1 and S2, are simultaneously paired with food, then behavior will continue to be controlled by S1 even when S2 is more consistently paired with food. S1 continues to control behavior since orientations to S1 are still intermittently followed by food. These results add plausibility to the view that the retardation of pecking produced by exposure to nondifferential light-food pairings is due to the multiple stimulus control of appetitive behaviors by concurrent stimuli in the experimental chamber.

EXPERIMENT II

When Gamzu and Williams (1971, 1973) reported that nondifferential light-food pairings result in suppressed rates of autoshaped pecking, they did not describe the types of behavior-environment interactions that occurred in the nondifferential pairing condition. In the nondifferential pairing condition, food was presented intermittently and independent of behavior, and as in experiments designed to study superstitious behaviors (Skinner, 1948; Staddon and Simmelhag, 1971), certain appetitive and nonappetitive behaviors were probably conditioned as a result of the interaction of variational factors (defined by Staddon and Simmelhag, 1971 as factors that initially give rise to certain behaviors) and the selective effect of adventitious reinforcement. As suggested earlier, various behaviors could have come under the control of environmental stimuli other than the lighted key in the nondifferential pairing procedure. If the latter suggestion were accurate, then stereotyped behavior should be observed in a nondifferential pairing condition and behavior should be controlled by various stimuli during the subsequent exposure to a differential pairing condition. The purpose of this experiment was to repeat the study by Gamzu and Williams with certain procedural modifications and to observe the types of behavior-environment interactions that occurred during successive exposure to differential and nondifferential pairing conditions.

Method

Subjects. The subjects were seven experimentally naive White Carneaux pigeons maintained at 80% of their free-feeding weight.

Apparatus. The apparatus used was essentially the same as that used in Experiment I. Although a different experimental chamber was used, the chamber was similar in all major respects to the chamber used in the first experiment.

Procedure. The birds were divided into groups of three and four birds on a random basis. Each bird received three days of magazine training and the procedure was similar to the first three days of magazine training in Experiment I. The only difference was that on day 3 of magazine training, the duration of food presentation was reduced to 3 sec at which point it was held constant throughout the experiment.

Following magazine training, each of the four birds in Group 1 was exposed to 15 sessions of a nondifferential pairing condition. During each session of the nondifferential pairing conditions, the CS was presented 50 times. The CS was a white light projected on the left key for 8 sec. On the average, every fourth presentation of the CS was followed by food independent of behavior. Thus, there were 13 CS-food pairings and 37 presentations of the CS alone within each session. The order of the CS-food pairings was irregular and no more than seven presentations of the CS alone could occur in succession. The CS was presented according to a VT 30-sec schedule and the component intervals of that schedule were generated by the progression suggested by Hoffman and Fleshler (1962) for N=20. During the intertrial interval, the key remained darkened.

During the intertrial interval (ITI), food was presented according to a VT 30-sec schedule that was arranged as the one described above. Thus, food was presented at equal rates (about once every 30 sec) in the presence and the absence of the CS. Both the food presentations in the intertrial interval and the CS were programmed by separate but identical tapes. This method for presenting food in the ITI and the CS was used so that the temporal relationship between all presentations of the CS and the food could be controlled. In the study by Gamzu et al., a probability generator was used to determine when food would be presented in the presence and absence of the CS. Therefore, food presentations were truly random, and Gamzu et al. had little control over the temporal relationship between the CS and food. It is desirable to have control over the temporal relationship between the CS and food so that changes in behavior can be related to the occurrence of events in the environment. For example, if conditioning of pecking had occurred in the nondifferential pairing procedure used by Gamzu and Williams, it would have been difficult to determine the antecedents of that pecking. In the latter procedure, pecking might sometimes be conditioned as a result of a large number of chance pairings of the CS and food.

In each session, the tape that determined CS presentations was started from a constant point. The tape that determined food presentation in the ITI was started from one of four specified points in a given session. Two of the four points were chosen such that an approximately equal number of trace and backward pairings of the CS and food would occur in a session. One of the four points was chosen such that the number of backward pairings of the CS and food together with the number of explicitly unpaired presentations of the CS and food exceeded the number of trace pairings of the CS and food. The last of the four points was chosen such that the number of trace pairings of the CS and food exceeded the number of backward pairings and unpaired presentations of the CS and food. In successive sessions, the sequence of starting points for the tape that determined food presentations in the ITI was 1, 2, 3, 4, 1, 2, etc.

Following the 15 sessions of the nondifferential pairing procedure, all birds in Group 1 were exposed to a differential pairing procedure. In the differential pairing condition, experimental sessions were exactly as before except that food was never presented during the ITI. That is, each session consisted of a mixture of 37 presentations of the CS alone and 13 CS-food pairings, and on the average, 30 sec elapsed between successive trials. For each bird, a five-minute portion of the last session of both the nondifferential and differential pairing conditions was filmed so that the behavior-environment interactions in both procedures could be observed carefully. Throughout both conditions, the behavior of each bird was observed casually but frequently.

The three birds in Group 2 were exposed to the differential pairing procedure immediately following magazine training. This group was included in order to insure that the conditioning of CS-directed pecking would occur as a result of differential CS-food pairings. After ten sessions of the differential pairing procedure, the birds in Group 2 were exposed to ten sessions of the nondifferential pairing procedure described above.

Throughout all conditions of the experiment, all experimental events were programmed to occur independent of the behavior of the birds, but pecks at the key were recorded.

Results And Discussion

For Group 1, all birds pecked at the CS at least several times during the nondifferential pairing condition. Bird 125 emitted three pecks at the CS, bird 2 emitted two pecks at the CS, and bird 126 emitted five pecks at the CS. For bird 123, pecking actually came to be controlled by the CS during the nondifferential pairing procedure. During session 10 of the nondifferential pairing condition, the tapes were arranged such that a high number of trace pairings of the CS and food occurred. The printed recording of the number of pecks that occurred within each trial showed that bird 123 began pecking just after a series of five CS-food pairings and trace pairings had occurred. Once pecking occurred, pecking was followed by food and was not only maintained but actually occurred more frequently over the subsequent sessions of the nondifferential condition.

For each bird in Group 1 except bird 123, stereotyped behaviors were acquired during the nondifferential procedure. Generally, behavior was quite variable before session 5, but behavior-stereotypy increased during sessions 5 through 9. Almost invariably, the stereotyped behavior consisted of rapid pacing movements back and forth along the control panel of the chamber. Some birds tended to pace mainly on the side of CS when the CS was present, but other birds continued to pace as they did in the absence of the CS. Since all birds pecked at the CS during the nondifferential procedure, the birds can be said to have attended to the CS. Also, the onset of the CS sometimes elicited mild startle responses even in the final sessions of the nondifferential pairing condition.

The stereotyped behaviors described above bear no obvious relation to the unconditioned stereotyped behaviors that have been observed in members of avian species that are kept in confinement (cf. Sargent and Keiper, 1967; Keiper, 1970). When domestic pigeons are in their home cages, the vigorous pacing behaviors observed in this experiment occur very rarely. Also, those behaviors are rarely observed when pigeons are confined in experimental chambers and are given continuous access to food.

Figure 2 shows for each bird in Group 1 the mean rate of pecking at the CS for the final three sessions in the nondifferential pairing condition and for all sessions in the differential pairing condition. Figure 2 shows that only bird 123, the bird that had pecked reliably in the nondifferential procedure came to peck the CS at a high rate during the differential pairing procedure. Birds 2 and 126 pecked very infrequently if at all during the sessions of this differential pairing condition, and bird 125 pecked at a moderately low rate in the presence of the CS. For all birds, very few pecks at the key occurred during the ITI.

Following the shift from the nondifferential to the differential pairing condition, the behavior of all birds in Group 1 became much more variable. During the first sessions of the differential condition, all birds emitted behavior that had either not been observed previously, or had not occurred since magazine training. The latter behaviors included standing in front of the observation window, pecking at the floor, and extended bouts of wing flapping. The increased behavioral variability may have resulted from the large decrease in the frequency of food presentations per session that occurred when the birds

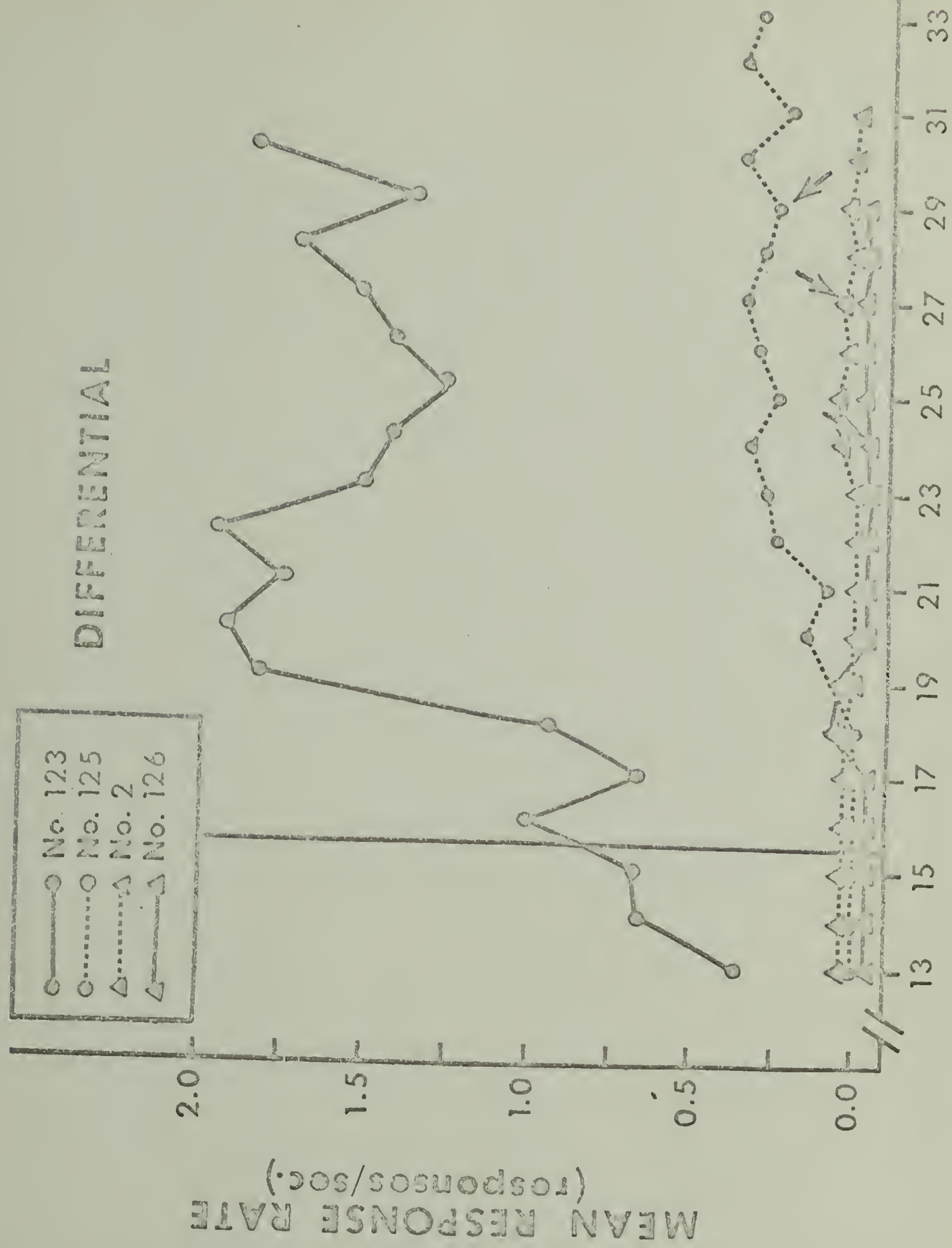

Figure 2. The mean rate of pecking at the CS for each bird in Group 1 of Experiment 2. The points to the left of the solid vertical line show the rate of response for the last three sessions of the nondifferential pairing procedure. The arrows indicate the point of transition from the differential pairing procedure to the 100% pairing procedure for each subject.

were shifted from the nondifferential condition to the differential condition. On the average, the birds had received 63 food presentations per session in the nondifferential condition while they received only 13 food presentations per session in the differential pairing condition.

Occasionally, the novel behaviors were by chance followed by food in the differential condition, and this type of behavior-environment interaction resulted in increased behavioral variability. For birds 2 and 126, food presentations seemed to most often follow variants of the pacing behavior that had been conditioned in the nondifferential procedure. Consequently, birds 2 and 126 continued to emit such nonpecking behaviors. However, for bird 125, food often followed a wide variety of behaviors. As a result, bird 125 came to emit pacing behaviors less frequently during the differential pairing condition, and conditioning of the key peck clearly took place for that bird. These observations suggest that when numerous behaviors are followed by food in the differential pairing conditions, the stereotyped behaviors that were conditioned in the nondifferential procedure cease to be "locked in" and pecking behavior can then be conditioned.

In sessions 19 through 21 of the differential pairing condition, there were drifts in the topography that had been conditioned in the nondifferential procedure. For all birds except bird 123, variants of the previous pacing behaviors began to occur most often in the area of the key both in the presence and the absence of the CS. During the trials, the birds sometimes oriented to and approached towards the CS and then paced in the region of the key until food was presented. During these sessions, bird 125 began to peck at the key more often and the pecking behavior was accompanied by small pacing movements and bobbing movements of the head.

Each bird in Group 1 was kept in the differential pairing condition for at least nine sessions and until the observed behaviors appeared stable over a period of four successive sessions. In the last sessions of the differential condition, the conditioned responses became more stereotyped and those behaviors came to be controlled by the CS. During the last session of the differential condition, five minutes of the session was recorded for each bird, and the behaviors were subsequently played back at normal speed and scored by means of a handswitch. No attempt was made to describe all behaviors that occurred during the five-minute period of observation. Rather, only those behaviors that were most clearly controlled by the CS were scored in order to measure the degree of stimulus control. The behaviors were scored in terms of duration rather than frequency since some of the behaviors were less discrete than others. Also, several different behaviors that appeared to be controlled by the CS were grouped together for scoring since the purpose for the scoring was to measure the degree of stimulus control.

Thus, for bird 125, pecking and head-bobbing movements were scored as members of a single category although those behaviors clearly differ in topography.

Table 1 shows for each bird in Group 1 the proportion of time (to the nearest second) during which the described behaviors occurred in the presence of the CS and during the ITI. Table 1 shows that the behavior of each bird was controlled by the CS. For three birds, there was a high degree of stimulus control while for bird 2, stimulus control was rather weak. The proportions shown in Table 1 were calculated by dividing the number of seconds during which the behavior occurred by the number of seconds of observation (in the CS or in the ITI). The proportion of time during which the behavior occurred is shown rather than the absolute amount of time since the absolute amount of time in the CS and ITI was different for each bird. The use of a relative measure such as a proportion facilitates the comparison of the behaviors of different birds. Although only a small sample of behaviors was scored, the data presented in Table 1 are consistent with the extensive casual observations made by the author.

After the behavior of the birds in Group 1 had stabilized in the differential pairing condition, all birds except bird 123 were exposed to a condition in which the CS was presented following the same intervals as before, but the CS was always paired with food. The shift from differential

TABLE 1

Table 1. The behaviors that were controlled by the light during Phase 2 of Experiment 2 for each bird in Group 1. The behaviors occurred in a 5-min portion of the last session of the differential pairing condition and were subsequently scored by hand as they were played back on the video monitor at normal speed. The proportions of time during which the behaviors occurred were calculated by dividing the number of seconds during which the behaviors occurred by the number of seconds of observation.

Bird	Behavior	# trials observed	Proportion of time during CS	Proportion of time during ITI
126	rapid vertical movements of the head below the key and in front of the speaker	8	.81	.14
125	pecks at the key; bobbing of the head up and down and side-to-side in the region of the key	10	.80	.03
2	stands still in front of the feeder and points the beak directly towards the key	7	.62	.37
123	pecks at the key	8	.91	.01

CS-food pairings to 100% CS-food pairings was made in order to determine whether the CS would come to control more pecking under pairing conditions that appear optimal for the conditioning of pecking behavior. The point at which the shift was made to 100% CS-food pairing condition is shown for each bird in Figure 2 by an arrow. As Figure 2 shows, high rates of pecking did not occur even when the CS was always paired with food. Indeed, the rate of pecking for bird 125 did not increase above the level that occurred when every fourth CS on the average was followed by food. Hence, it seems unlikely that the pecking was directly engendered by CS-food pairings.

The retardation of autoshaped pecking that occurred for three of the four birds in Group 1 was not due to attentional factors. If the birds had failed to attend to the CS, then the CS would not have controlled as it did the previously described behavior in the differential pairing procedure. The fact that the CS did come to control behavior shows that the retardation of pecking did not result from the birds having learned that there was a zero correlation between the occurrence of the CS and the presentation of food. It seems unlikely that the retardation effect can be adequately characterized as "learned laziness" (cf. Enberg et al., 1971) since behaviors were definitely conditioned in the nondifferential pairing condition. In fact, the pacing behaviors that were conditioned were quite vigorous.

The possibility remains that the parameters of the differential condition were not sufficient to reliably result in the conditioning of CS-directed pecking. The data of Group 2 permit the rejection of that possibility. Figure 3 shows the rate of pecking during the CS for each of the three birds in Group 2. Within 8 sessions of exposure to the differential pairing condition, all birds were pecking at rates of at least 0.75 per sec. As in many experiments on autoshaping, there was much variability of response rates between birds. The origins of that variability are currently unknown.

In the nondifferential pairing condition, the rate of pecking declined to levels near zero for two of three birds in Group 2. Interestingly, the decrease in the rate of pecking was accompanied by the acquisition of very stereotyped behaviors in the ITI. Even in the first session of the nondifferential pairing procedure, the behaviors that were conditioned in the ITI continued to occur during CS and so were occasionally followed by food in the presence of the CS. For bird 153, there was a sharp decline in the rate of pecking during the first session of the nondifferential pairing procedure and stereotyped behaviors in the ITI were conditioned in that session. However, bird 153 for unknown reasons sometimes pecked rapidly in the presence of the CS and sometimes emitted the stereotyped nonpecking behavior. Due to the nature of the procedure, it was a matter of chance

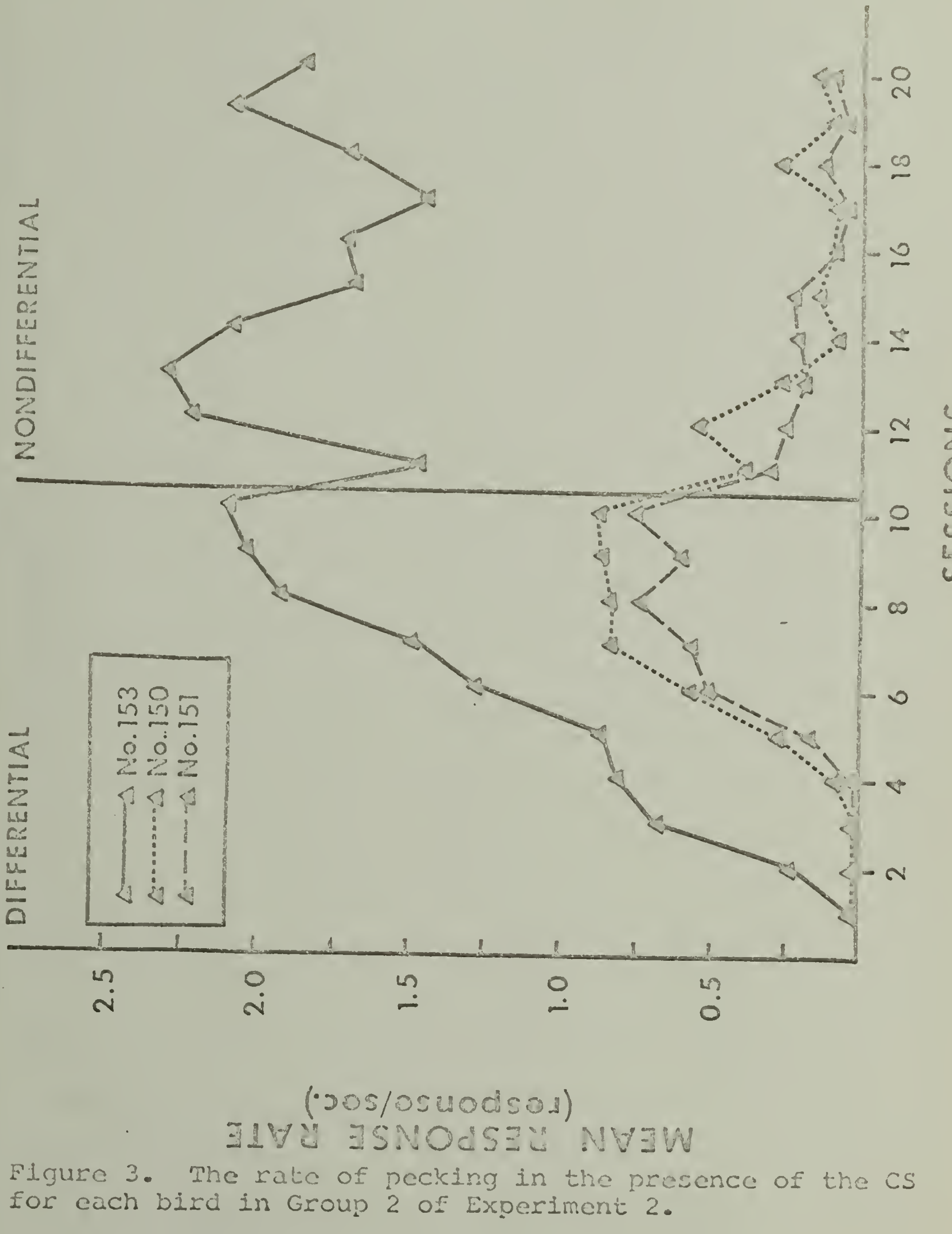

Figure 3. The rate of pecking in the presence of the CS for each bird in Group 2 of Experiment 2.

as to whether the pecking or nonpecking behavior was followed by food in the presence of the CS. While pecking was maintained at a high rate for bird 153, the frequency of occurrence of pecking and nonpecking behaviors fluctuated in a cyclical and inverse manner.

Gamzu and Williams (1971, 1973) reported that autoshaped pecking occurred infrequently following a shift from a differential to a nondifferential condition and they interpreted that effect as showing that autoshaped pecking was not maintained by adventitious reinforcement. However, the observations of the behaviors of the birds in Group 2 suggest an alternative interpretation. Both CS-directed behaviors and behaviors not directed towards the CS are conditioned by adventitious reinforcement in the nondifferential pairing procedure, and neither class of behavior is highly controlled by the CS since the same behaviors can be (and are) followed by food equally often in the presence and absence of the CS. Whether pecking is maintained in a nondifferential pairing condition is largely a matter of chance. The nondifferential procedure may be seen as consisting of a mult VT 30-sec schedule of reinforcement in which the component stimuli are unequal in duration. One component (no CS present) is associated with the adventitious reinforcement of behaviors not directed towards the key. The component of lesser duration (CS present) is associated with the adventitious reinforcement of both

CS-directed behaviors and behaviors not directed towards the key. Which behavior predominates in the presence of the CS is beyond the control of the experimenter.

There remain at least two plausible accounts of the results of this experiment. First, it may be that for Group 1, appetitive and nonappetitive behaviors in the nondifferential procedure were conditioned and controlled by numerous concurrent stimuli in the experimental chamber. For example, as the stereotyped pacing behaviors were acquired, the birds were moving their heads past certain parts of the front wall of the chamber so binocular orientations occurred to a fixed set of features. During the differential pairing procedure, the behavior of the birds might have been under conditional stimulus control. That is, nonpecking behavior may have come to be controlled by a subset of the original set of controlling stimuli given that the CS was present. This account is plausible in that orientations to aspects of the environment other than the CS could be followed by food only in the presence of the CS in the differential pairing procedure. Perhaps only some birds pecked at the CS in the differential procedure because by chance, their orientations to the CS were most often followed by food. Other birds may have oriented first to the CS and then to other features, thus providing the conditions for the acquisition of conditional stimulus control. This interpretation stresses the control of behavior by concurrent stimuli.

A second account of the results for Group 1 is that pacing behaviors were conditioned by adventitious reinforcement in the nondifferential condition and that variants of those behaviors continued to be followed by food in the differential condition. Consequently, these behaviors came under stimulus control of the CS and interfered with the acquisition of pecking. In other words, the non-pecking behaviors competed with the pecking behaviors. This interpretation centers about the notion of response competition.

The observations made in this experiment are consistent with both of the latter accounts and further experiments are necessary for substantiating either account. It should be noted that the two foregoing accounts are similar in some ways. For example, the account in terms of control by concurrent stimuli might involve the notion of response competition since orientations to features other than the CS could be said to interfere with pecking. Likewise, the non-pecking behaviors that are the basis of the account in terms of response competition may be partially under the control of the CS and partially under conditional stimulus control of aspects of the environment other than the CS.

EXPERIMENT III

The purpose of this experiment was to determine whether the retardation of autoshaped pecking that results from nondifferential light-food pairings can be accounted for in terms of competition between pecking and non-pecking behaviors. In Experiment II, pacing behaviors were conditioned in the nondifferential pairing procedure. When extinction was programmed during the ITI, the behavior of the birds became much more variable in both topography and frequency, and pecking seemed to be acquired only if the nonpecking behaviors became highly variable. The acquisition of pecking seemed to occur mainly after the variable responses were followed several times by food. When variants of the pacing behaviors were followed by food regularly, those nonpecking behaviors were maintained and came to be controlled by the light. Since food was presented independent of behavior, it was a matter of chance as to which behavior would be followed by food. If the retardation effect results from competition between pecking and nonpecking behaviors, then pecking should not be conditioned in the differential pairing procedure if only the nonpecking behaviors that were conditioned in the nondifferential procedure were followed reliably by food. In this experiment, an attempt was made to provide such optimal conditions for the maintenance of nonpecking behaviors that might compete with pecking behaviors.

In order to test the account of the retardation effect in terms of response competition, three conditions must be satisfied. First, one must expose the birds to a condition in which the temporal relation between CSs and food is similar to that in the nondifferential pairing condition. Second, only the behaviors that are conditioned in the nondifferential pairing condition should be followed immediately by food during the exposure to the differential pairing condition. Third, the behaviors that one arranges to be followed by food in the differential pairing procedure should be similar to the behaviors that are typically conditioned in a nondifferential pairing procedure like that of Experiment II.

Schedules of reinforcement provide a convenient means for satisfying all the above conditions. For example, a schedule may be arranged so that only certain responses are followed by food and a lighted key is paired with food in a differential manner. One variant of the latter type of schedule may be designated as follows: mult (EXT) (mix EXT FI 8-sec). In this schedule, one component of the multiple schedule is associated with extinction (EXT) while the other component is associated with a mixed schedule of reinforcement. A mixed schedule is one in which the same exteroceptive stimulus is associated sometimes with one schedule of reinforcement and sometimes with another. In the above schedule, the absence of the light is correlated with extinction while the presence of the light is sometimes associated with extinction and sometimes with a schedule in which the first response at the end of 8 sec is reinforced (FI 8-sec). When the FI 8-sec schedule is on the average effective in only 25% of the presentations of the light, when the duration of the extinction component of the mixed schedule is fixed at 8 sec, and when the duration of the extinction component of the multiple schedule is 30 sec on the average, the light-food pairing conditions are very similar to those of the differential pairing condition in Experiment II (assuming that the specified responses occur). Likewise, a schedule may be arranged so that certain responses are followed by food and a lighted key is paired with food in a nondifferential manner. That schedule may be designated as follows: mult (VI 30-sec) (mix EXT FI 8-sec).

This experiment was designed so that pigeons were exposed to nondifferential light-food pairing and then to differential light-food pairings, but all pairings were contingent upon specified responses so as to provide control over which responses preceded food. If the retardation effect were due to the occurrence of competing responses, then pecking should not be conditioned when some nonpecking behavior is reinforced first according to a mult (VI 30-sec) (mix EXT FI 8-sec) schedule of reinforcement and then according to a mult (EXT) (mix EXT FI 8-sec) schedule of reinforcement. In utilizing schedules of response-dependent reinforcement, one assumes that the effects of light-food pairings are independent of whether the pairing is contingent upon the occurrence of a response. This assumption has recently been supported by the results of numerous experiments that have been reviewed comprehensively by Gamzu and Schwartz (in press) and so will not be described here.

The response that was selected for analysis in this experiment consisted of a raising of the head while standing near the control panel on the same side as the key which was illuminated periodically. The head raising response was chosen because it was observed in a pilot study that the response was similar in form to the pacing movements that were observed in the nondifferential pairing procedure of Experiment II. When the head raise was conditioned, it consisted of pacing movements together with a lifting of the head. Also, the head-raise was selected for study since it was found to be sensitive to contingencies of reinforcement.

Method

Subjects. The subjects were 21 experimentally naive White Carneaux pigeons maintained at 80% of their free-feeding weight.

Apparatus. The same apparatus used in Experiment II was used in this experiment. However, both experimental chambers were modified in several ways so that the head-raising responses could be recorded automatically by means of a photosensitive circuit. A metal tube that was 0.32 cm in diameter was mounted parallel to the control panel and was flush to the wall on the left side of the chamber. The tube was placed 3.81 cm from the ceiling and 3.81 cm from the control panel of the chamber. Inside of the chamber, the tip of the tube and the surrounding region of the wall that was intersected by the tube were covered by a sheet of clear plastic. The plastic covering served to prevent the birds from nibbling the tube or changing the position of the tube by pecking at it. Black construction paper was placed between the wall and the plastic cover and a hole in the black paper permitted light to enter the chamber through the tube. The lip of the tube was surrounded by black paper so that the lip of the tube might not be a highly salient feature that elicited pecking.

The tube served to aim a beam of light across a space of 17.78 cm to a photosensitive transistor (NIP Photodarlington). The source of the light was a Westinghouse superbeam headlamp (No. 6014) that was positioned outside of the chamber and was operated at 12V dc. A Kodak No. 87 filter was placed between the light source and the tube so that most of the wavelengths in the visible region of the spectrum would not pass into the chamber. When looking directly into the tube from the inside of the chamber, only dull red light could be seen.

The photosensitive transistor was mounted on a block of wood at the end of a shaft bored in the wood. The shaft was 3.18 cm long and 0.32 cm in diameter and served to insure that the photosensitive transistor would be affected only by light that was precisely aimed from the source outside of the chamber. When the transistor was mounted at the end of the narrow shaft, the transistor was not affected by any light in the chamber that might have reflected from the head of the subject. The photosensitive transistor was positioned 3.81 cm from the ceiling, 3.81 cm from the front panel of the chamber, and 17.78 cm from the side of the chamber that was intersected by the tube. The block of wood on which the transistor was mounted was placed just to the right of the houselight and did not cast any shadows on the left key. The entire block was painted flat black so that no light from the houselight was reflected by the block.

The beam of light and the photosensitive transistor were placed so that the beam of light would be interrupted whenever the pigeon's head was held 33.02 cm from the floor and about 4 cm from the left side of the front panel of the chamber. The photobeam could be broken by the head of the pigeon only if the bird were standing in a very erect manner.

Procedure. The birds were divided on a random basis into six groups. Four groups each contained four birds, one group contained three birds, and one group contained two birds. Each bird received four days of magazine training. The first three days of magazine training were identical to that of Experiment II. On the fourth day of magazine training, food was presented for a fixed duration of 3 sec according to a VT 30-sec schedule. Four days of magazine training were given to insure that all birds ate readily from the feeder at the start of the experimental session. It was especially important for the birds in this experiment to be trained well to eat from the feeder since two birds were studied simultaneously and the author could not observe both birds during the early experimental sessions.

The different groups and the conditions to which they were exposed are summarized in Table 2. Before considering the treatment for each group in detail, some general features of the experimental procedure will be described. During the initial sessions of Phase 1, the head-raising response was shaped according to the method of successive approximation for all birds that were exposed to schedules in which reinforcement was response-dependent. The birds differed in height, and some birds were so short that the desired head-raise could be emitted only with great effort. For those birds, the floor of the chamber was raised either 1.27 cm or 2.54 cm with blocks of wood. In pilot studies, it had been found that raising the floor of the chamber by such small amounts does not interact with the effects of light-food pairings.

Several aspects of the mult (VI 30-sec) (mix EXT FI 8-sec) schedule described above should be considered here. When that schedule was in effect, light and food presentations occurred at about the same interval and in the same temporal relationship as in Experiment II. The same tapes that had been used to program the VT schedules of Experiment II were used to program the VT and VI schedules according to which,

Table 2

The experimental conditions during Phases 1 and 2 for each group of birds in Experiment 3.

Group	Phase 1	Phase 2
1 (N=4)	mult (VI 30-sec)(mix EXT FI 8-sec)	mult (EXT)(mix EXT FI 8-sec)
2 (N=4)	nondifferential pairings, yoked	differential pairings (25%), yoked
3 (N=2)	mult (EXT)(mix EXT FI 8-sec)	
4 (N=4)	mult (VI 30-sec)(mix EXT FI 8-sec)	mult EXT FI 8-sec
5 (N=4)	nondifferential pairings, yoked	100% pairings, yoked
6 (N=3)	mult EXT FI 8-sec	

respectively, the left key was lighted and food was presented in the absence of the light. In order to control the temporal relationship between the lighted key and food, the VT schedule for presenting the lighted key was inoperative when the VI 30-sec tape locked up. Thus, when a hole in the VI 30-sec tape was reached, both tapes stopped running until a head-raise occurred and food was presented. If the VT tape had been allowed to operate while the VI tape was locked up and if several seconds elapsed without the occurrence of a head-raise, then there would have been little control over the number and sequence of trace and backward pairings of the lighted key and food.

For the birds in the condition in which reinforcement was contingent upon responses, the amount of time spent in the presence and absence of the lighted key was dependent upon the behavior that occurred. Since the duration of the light and the ITI could vary both between and within subjects, the durations of the light and the ITI were measured and recorded daily.

Now the experimental treatment for each group will be described in detail. In Phase 1 of the experiment, the birds in Group 1 were exposed for 15 sessions to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule of reinforcement. During Phase 2, those birds were exposed to the mult (EXT) (mix EXT FI 8-sec) schedule that was described above. Thus, the birds in Group 1 were exposed sequentially to nondifferential and differential light-food pairings in a manner similar to the subjects in Experiment II except that food was contingent upon head-raising for the birds in Group 1 of this study. Since food was contingent upon head-raising, the durations of the periods of illumination and nonillumination of the key were also partially contingent upon head-raising. Since the effects of light-food pairing depend upon the duration of the light and the duration of the ITI (Terrace, Gibbon, Farrell and Baldock, in press), the effects of presenting food contingent upon head-raising were potentially confounded with the effects of variations in the duration of the ITI and the light on the key. Therefore, Group 2 was run in order to insure that the temporal relationship between light and food presentations for Group 1 was sufficient to produce results like those obtained in Experiment II. The birds in Group 2 served as the yoked partners to the birds in Group 1. A given bird in Group 2 received presentations of the light and food whenever the corresponding bird in Group 1 received presentations of the light and food. However, those presentations always occurred independently of the behavior of the birds in Group 2. Retardation of pecking was expected to occur strongly for each bird in Group 1 while some birds in Group 2 were expected to acquire pecking (depending upon what behaviors were most reliably followed by food in Phase 2).

The birds in Group 3 were exposed to the mult (EXT) (mix EXT FI 8-sec) schedule without prior exposure to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule of reinforcement. If pecking were conditioned for the birds in Group 3, but not for the birds in Group 1, then the retardation of pecking for the birds in Group 1 could be attributed to the exposure to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule. The birds in Group 3 were trained during the first session to raise their heads. In order to facilitate the shaping of head-raising, the frequency of reinforcement was increased in session 1. Food was never presented during the ITI, but on the average, 50% of the light presentations were associated with the FI 8-sec schedule of reinforcement.

Groups 4 and 5 were treated in Phase 1 in the same way as Groups 1 and 2 respectively. In Phase 2, the birds in Group 4 were exposed to a mult (EXT FI 8-sec) schedule of reinforcement. In that schedule, a key was lighted according to a VT 30-sec schedule, and the first head-raise in the presence of the light at the end of 8 seconds was followed by food. Since the light was always paired with food, the light-food pairing conditions for Groups 4 and 5 were more favorable for the acquisition of pecking than were the light-food pairing conditions for Groups 1 and 2. However, for the birds in Groups 4 and 5, the nonpecking responses acquired in Phase 1 would continue to be followed by food frequently in Phase 2. Therefore, the nonpecking behaviors should compete with pecking behaviors even though the light is always paired with food.

The birds in Group 6 were exposed only to the mult EXT FI 8-sec schedule of reinforcement. The birds in Group 4 were exposed to that schedule following exposure to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule. Differences in the behavior of the birds in Groups 4 and 6 could be attributed to the exposure of the birds in Group 4 to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule of reinforcement.

Results

All birds in Group 1 acquired the head-raising response quite readily and the response rate of each was greater than 0.50 responses per second by the end of Phase 1. Figure 4 shows the mean response rate for each bird in Group 1 during Phase 1 and 2 of the experiment. During Phase 1, there were no systematic differences in the rate of responding in the presence and the absence of the lighted key. The topography of the head-raising response varied considerably between subjects. For example, during the last session of Phase 1, bird 171 often broke the photobeam by pecking at the block of wood in which the photosensitive transistor was mounted. In contrast, bird 191 broke the beam by pacing back and forth along the left side of the front wall with the head held erect. Bird 171 was the only bird in Group 1 for which a pecking response was conditioned during Phase 1, and the other three birds most often broke the beam by pacing with the head held high.

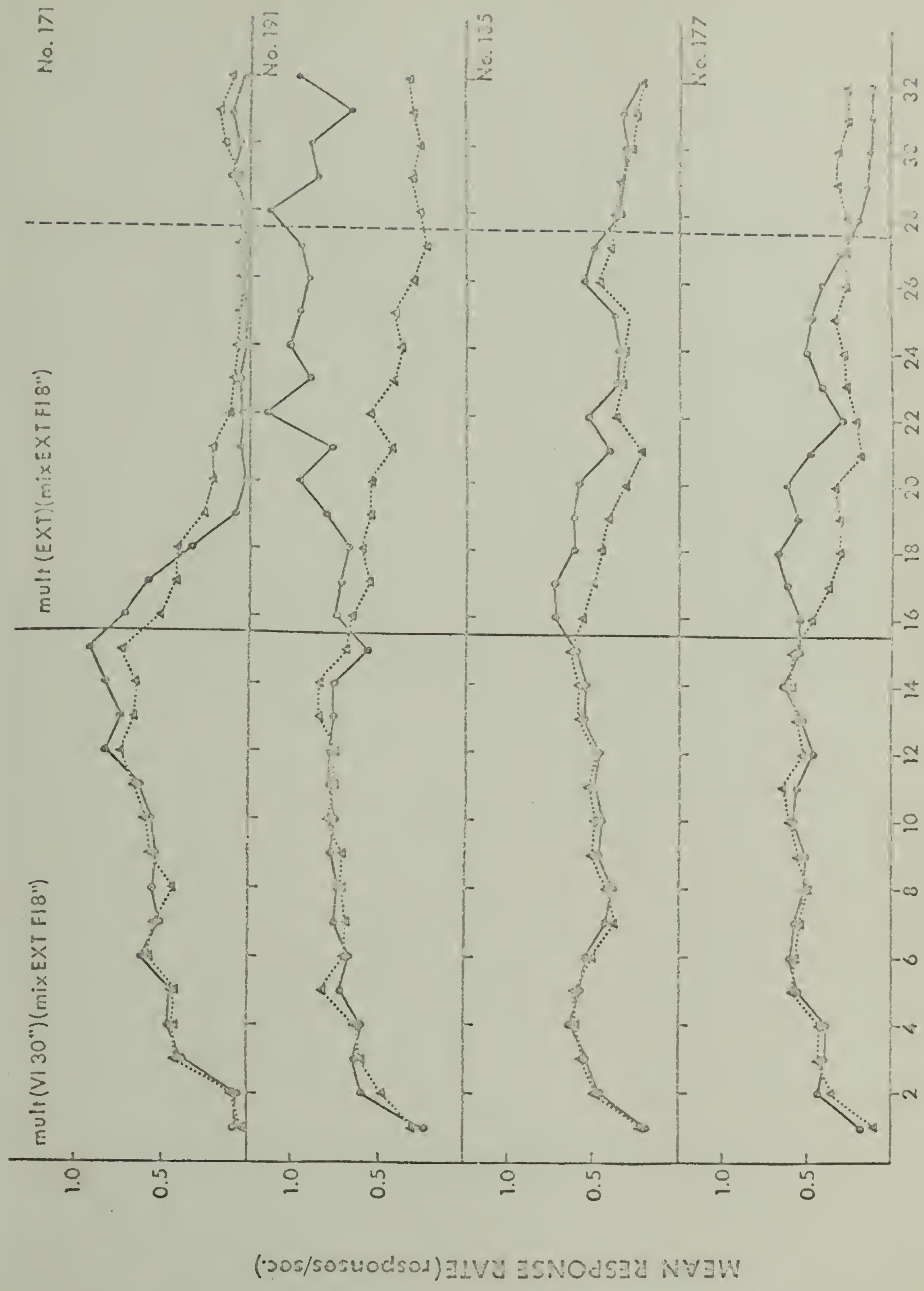

Figure 4. The mean rate of head-raising for each bird in Group 1 of Experiment 3. The broken vertical line indicates the point at which the feedback stimulus was introduced. The circles show the response rate during trials while the triangles show the response rate during the ITI.

During Phase 1, the form of the conditioned response varied over sessions for individual subjects. For example, the response for bird 171 initially consisted of a pacing movement along with rapid up and down movements of the head. However, the behavior of bird 171 (and most other birds) was often more variable at the start of an experimental session than at the end of the session, and during sessions 8 through 11, pecks sometimes occurred at the beginning of a session and were followed by food. As a result, pecks at the block occurred more frequently, and by the final session of Phase 1, approximately 10% of all interruptions of the photobeam were due to pecks at the block. Likewise, bird 191 paced along different portions of the left side of the front wall in different sessions in Phase 1. During Phase 1, pecks at the key occurred very infrequently for all birds.

During the initial sessions of Phase 2, the behavior of all birds became highly variable. The increased variability of the behavior could have been due to the decrease in the mean number of food presentations per session from 63 in Phase 1 to 13 in Phase 2. Also, a wide variety of behaviors could have had the same effect on the experimental environment since the photobeam could have been interrupted by a variety of different responses and from a number of different positions. As behavior became more variable, the form of the responses for all birds in Group 1 drifted towards the form of pecking responses. For example, bird 191 came to break the photobeam by rapidly moving the head up and down with the beak pointed downwards so that the response resembled pecking. For that bird, the head movements occurred about 2.5 cm to the left of the key, and the photobeam was often interrupted when the head was lifted upwards. For other birds, the head-raising response and the pecking responses were not integrated into a single type of response as they were for bird 191. The behavior of the birds other than bird 191 came to consist of key-directed behaviors and of behaviors like the pacing movements described earlier that were not directed towards the key. Bird 177, for example, emitted many pecks at the lighted key that did not actually contact the key, and pecks at the key were often followed by a head-raise that bore little resemblance to the pecking responses.

For three of four birds in Group 1, the lighted key did not come to control responses that interrupted the photobeam during Phase 2. Although head-raises were reinforced intermittently in the presence of the light and were never reinforced in the absence of the light, the lighted key failed to control responses that interrupted the photobeam for all the birds except bird 191. Interestingly, the lighted key came to control the head-raises of bird 191 only after the pecking movements for that bird became directed towards the key rather than the portion of the wall 2.5 cm to the left of the key. In effect, the light controlled pecking in bird 191 after key-directed pecks had been followed by food in the presence of the light but not in the absence of the light. Furthermore, the lighted key acquired control over key-directed responses in all birds and in three of four instances, the light controlled pecks at the key.

Table 3 shows the rate of pecking at the key in the presence and absence of the light for each bird in Group 1. The pecking of birds 171 and 177 was clearly controlled by the light. Also, the pecking of bird 191 was controlled by the light, but most of the pecks fell short of the key and so were not recorded. Since many unmeasured pecks at the key were emitted by most birds, pecking was scored by hand during a portion of two sessions. During the first five minutes of sessions 26 and 27, all pecks at the key were measured for each bird. A peck at the key was defined as a sharp thrusting forward of the head with the beak aimed directly at the key. Pecks were recorded by the operation of a hand switch by the author while he viewed the behavior on the video-monitor as it occurred in the experimental chamber. The rate of pecking as measured by direct observation is shown in parentheses for each bird in Table 3. The pecking of all birds except bird 185 was clearly controlled by the light even though for birds 171 and 177 there was poor discriminative control of responses that interrupted the photobeam. Although the light did not control pecking for bird 185, the light did control rapid vertical and horizontal movements of the head in front of the key.

Table 3

The mean rate (responses per sec) of recorded pecking at the key during the trials and during the intertrial intervals for each bird in Group 1 of Experiment 3. The rates of pecking for each bird as determined by observation during sessions 26 and 27 are shown in parentheses.

Session	bird 171		bird 191		bird 185		bird 177	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
16	0	0	0	0	0	0	0	.01
17	.05	0	0	0	0	0	.01	0
18	.07	0	0	0	0	0	0	.01
19	.20	0	0	0	0	0	0	.01
20	.26	.01	0	0	0	0	.05	0
21	.31	.01	0	0	0	0	.08	0
22	.20	.01	0	0	.01	0	.12	0
23	.33	.01	0	0	.04	0	.03	0
24	.20	0	0	0	.05	0	.03	0
25	.39	0	0	0	.06	0	.03	0
26	.22 (.62)	0 (0)	0 (1.16)	0 (.08)	.02 (.07)	0 (0)	.13 (.71)	.01 (.04)
27	.23 (.49)	0 (0)	0 (1.1)	0 (.11)	.01 (.06)	0 (0)	.17 (.60)	0 (.01)

Table 3 (cont'd.)

Session	bird 171		bird 191		bird 185		bird 177	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
28	.23	0	0	0	.02	0	.27	0
29	.29	0	0	0	.03	.01	.36	.02
30	.18	0	0	0	.02	0	.58	.01
31	.13	0	0	0	.04	0	.60	.01
32	.13	0	0	0	.07	0	.61	.04

Following session 27, an attempt was made to increase the control of the light over responses that interrupted the photobeam. Three of four birds in Group 1 had been emitting sequences of pecking and head-raising responses. Although head-raises were immediately followed by food, pecks at the key were also followed by food after a short delay. Poor discriminative control of head-raises might result if head-raises had sensory consequences that were difficult to discriminate. To eliminate that possibility, a feedback signal was arranged so that each interruption of the photobeam resulted in the offset of the white noise for a brief (about .10 sec) period of time.

The results of adding feedback for head-raises are shown in Figure 4 to the right side of the broken vertical line. The addition of the feedback stimulus did not facilitate the discriminative control of head-raising by the light. The feedback stimulus did appear to be discriminable for the birds since all birds oriented towards the speaker when the feedback stimulus was first added. Although the rate of head-raising for bird 171 increased when the feedback stimulus was introduced, the response rate in the absence of the light increased more than in the presence of the light. Also, the addition of the feedback stimulus did not result in any marked changes in response topography. The stability of the form of responses is unsurprising since the responses that were acquired following the shift from

Phase 1 to Phase 2 had been followed by food on many occasions before the addition of the feedback signal.

In Phase 2, there was poor discriminative control of head-raising and behavioral contrast did not occur for most birds. Behavioral contrast may be said to occur when the experimenter alters one component of a multiple schedule (for example, by changing the schedule of reinforcement from VI 30-sec to EXT) and subsequently observes that the response rate in the other component increases even though the latter component remains unaltered. In this experiment, the schedule of reinforcement associated with the presence of the light was the same in Phases 1 and 2, while the schedule of reinforcement associated with the absence of the light was changed from VI 30-sec to extinction. Thus, the conditions that typically produce behavioral contrast when the pecking response of pigeons is studied were met in this experiment. Nevertheless, there was evidence for the occurrence of behavioral contrast only for bird 191. It is of interest that some behavioral contrast did occur for bird 191, for as described earlier, that bird often emitted responses that involved the integration of pecking and head-raising movements. For all other birds in Group 1, induction occurred. That is, as the rate of response decreased in the absence of the light, the rate of response in the presence of the light decreased too.

In this experiment, the durations of the periods of presence and absence of the lighted key were similar for all subjects in Group 1 except bird 171. Table 4 shows the mean duration of the presence and absence of the lighted key for each bird in Phases 1 and 2. After the first few sessions of Phase 1, there were few pauses in responding and so the duration of the presence of the lighted key approached the minimum value of 8.0 sec and the mean duration of the ITI approached 30 sec. However, in Phase 2, pausing tended to occur more often and so the mean duration of the key increased. For bird 171, head-raising was barely maintained and so there was a large increase in the mean duration of the periods of illumination of the key. Generally, the durations of the light and the ITI did not appear to be related systematically to the behavior of different birds.

The birds in Group 2 were yoked to the birds in Group 1 and so were exposed in Phase 1 to nondifferential light-food pairings that occurred independently of behavior. For the birds, in Group 2, pecking at the key did not occur reliably during Phase 1. For birds 172, 184, 186 and 182, respectively, the total number of pecks at the key during Phase 1 were 0, 1, 0, and 2. As in Experiment II, various nonpecking behaviors were conditioned during Phase 1. These behaviors consisted of pacing movements for all birds.

During Phase 2, when differential light-food pairings occurred for the birds in Group 2, only bird 184 came to peck at the lighted key at a high rate. It is interesting to note presence and absence of the lighted key were similar for all subjects in Group 1 except bird 171. Table 4 shows the mean duration of the presence and absence of the lighted key for each bird in Phases 1 and 2. After the first few sessions of Phase 1, there were few pauses in responding and so the duration of the presence of the lighted key approached the minimum value of 8.0 sec and the mean duration of the ITI approached 30 sec. However, in Phase 2, pausing tended to occur more often and so the mean duration of the key increased. For bird 171, head-raising was barely maintained and so there was a large increase in the mean duration of the periods of illumination of the key. Generally, the durations of the light and the ITI did not appear to be related systematically to the behavior of different birds. The birds in Group 2 were yoked to the birds in Group 1 and so were exposed in Phase 1 to nondifferential light-food pairings that occurred independently of behavior. For the birds in Group 2, pecking at the key did not occur reliably during Phase 1. For birds 172, 184, 186 and 182, respectively, the total number of pecks at the key during Phase 1 were 0, 1, 0, and 2. As in Experiment II, various nonpecking behaviors were conditioned during Phase 1. These behaviors consisted of pacing movements for all birds.

During Phase 2, when differential light-food pairings occurred for the birds in Group 2, only bird 184 came to peck at the lighted key at a high rate. It is interesting to note

TABLE 4

The mean duration of the trials and the intertrial intervals for each bird in Group 1 of Experiment 3. The corresponding yoked subject in Group 2 is shown in parentheses for each bird.

Session	bird 171(172)		bird 191(184)		bird 185(186)		bird 177(182)	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
1	9.8	34.6	9.6	31.5	8.6	28.5	9.6	33.7
2	10.7	34.8	9.8	30.6	9.2	30.1	8.6	30.9
3	9.6	29.6	8.3	30.5	8.4	29.6	8.5	29.7
4	8.4	30.8	8.3	32.1	8.3	29.1	8.6	30.2
5	8.1	30.1	8.1	28.7	8.3	28.7	8.2	28.7
6	8.5	29.1	8.6	28.7	8.4	29.0	8.2	29.0
7	8.4	30.0	8.1	28.6	8.4	29.8	8.1	28.6
8	8.5	31.2	8.4	29.1	8.4	29.7	8.4	29.5
9	9.0	29.3	8.1	28.3	8.6	29	8.4	28.8
10	9.2	29.6	8.2	28	9.0	28.4	8.2	28.7
11	8.6	28.5	8.1	28.2	8.4	28.7	8.2	28.8
12	8.2	30.9	8.4	28.3	8.3	28.4	8.1	29.0
13	8.2	29	8.3	28.2	8.3	29.1	8.1	29.0

TABLE 4 (cont'd.)

Session	bird 171(172)		bird 191(184)		bird 185(186)		bird 177(182)	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
14	8.2	29.2	8.1	28.1	8.1	28.9	8.2	29.2
15	8.1	29.4	8.4	28.9	8.4	30.5	8.2	28.5
16	8.4	30.9	8.3	30.9	8.3	30.9	8.5	30.9
17	8.3	30.9	8.4	30.9	8.2	30.9	8.2	30.9
18	8.6	30.9	8.3	30.9	8.2	30.9	8.2	30.9
19	9.7	30.9	8.5	30.9	8.2	30.9	8.4	30.9
20	12.5	30.9	8.0	30.9	8.2	30.9	8.2	30.9
21	9.5	30.9	8.3	30.9	8.8	30.9	12.4	30.9
22	10.3	30.9	8.1	30.9	8.3	30.9	11.8	30.9
23	9.4	30.9	8.1	30.9	8.3	30.9	9.1	30.9
24	14.1	30.9	8.0	30.9	8.5	30.9	8.9	30.9
25	10.9	30.9	8.9	30.9	8.2	30.9	8.2	30.9
26	13.7	30.9	8.8	30.9	8.0	30.9	8.5	30.9
27	11.6	30.9	8.5	30.9	8.2	30.9	9.8	30.9

TABLE 4 (cont'd.)

Session	bird 171(172)		bird 191(184)		bird 185(186)		bird 177(182)	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
28	13.9	30.9	8.4	30.9	8.6	30.9	9.8	30.9
29	8.9	30.9	9.3	30.9	8.2	30.9	9.7	30.9
30	9.9	30.9	9.1	30.9	8.4	30.9	10.2	30.9
31	9.1	30.9	9.5	30.9	8.4	30.9	10.1	30.9
32	10.8	30.9	8.2	30.9	8.7	30.9	12.8	30.9

that even though the stimulus-reinforcer variables were the same for Groups 1 and 2, pecking was conditioned in Phase 2 for three of four birds in Group 1 but for only one bird in Group 2. Table 5 shows the rate of pecking in the presence and absence of the lighted key for birds 184 and 186 during Phase 2. The rates of pecking for birds 172 and 182 were virtually zero and so were not included in Table 5. The conditioning of pecking for bird 184 probably did not result from the durations of the lighted key and the ITI for that bird. As shown in Table 4, the duration of the light and the ITI for bird 184 was similar to those of at least two other birds, yet only bird 184 acquired pecking.

Observation of the birds in Group 2 during Phase 2 showed that the lighted key came to control the behavior of all birds. As in Experiment II, the lighted key came to control variants of the pacing behaviors that had been conditioned in Phase 1. For bird 184, pecking began to occur frequently after behavioral variability had increased and after a variety of responses were followed by food during the differential pairing procedure.

The birds in Group 3 that were exposed only to the mult (EXT) (mix EXT FI 8-sec) schedule of reinforcement did not come to raise their heads mainly in the presence of the lighted key. Figure 5 shows the rate of head-raising in the presence and the absence of the light for both birds in Group 3. Figure 5 shows that there was poor discriminative

TABLE 5

The mean rate (responses per sec) of pecking during the trials and the intertrial intervals for two of the birds in Group 2 during Phase 2 of Experiment 3.

Session	bird 184		bird 186	
	trial	ITI	trial	ITI
16	0	0	0	0
17	.04	0	0	0
18	.58	.01	0	0
19	.96	.02	0	0
20	1.47	.04	0	0
21	1.19	.05	0	0
22	1.04	.04	0	0
23	1.50	.04	0	0
24	1.45	.07	.01	0
25	1.72	.06	.02	0
26	1.25	0.5	.03	.01

control of head-raising even after 12 sessions. However, the light acquired control over key-directed behaviors after several sessions. Bird 197 frequently emitted unrecorded pecks at the key in the presence of the light but not during the ITI. As determined by the observation and scoring of 2 five-minute portion of session 12, the rates of pecking in the presence and absence of the light for bird 197 were 0.46 per sec and 0.04 per sec respectively. Bird 143 rarely pecked at the key but made frequent nibbling movements of the beak that were clearly controlled by the light.

During Phase 1, the birds in Group 4 behaved similarly to the birds of Group 1. Bird 173 was the only subject in Group 4 that reliably interrupted the photobeam by pecking. Throughout the first nine sessions of Phase 1, bird 173 interrupted the photobeam by pacing and head-raising. Occasionally, bird 173 pecked at the tube through which the light from outside of the chamber passed. Pecks at the tube initially occurred at the beginning of the session, but after those pecks had been followed by food on numerous occasions, pecking responses became more frequent than the head-raises. The pecking responses of bird 173 may have been shaped by contingencies of reinforcement that were beyond the control of the experimenter. Before pecking occurred frequently, pacing movements were often accompanied by frequent monocular orientations towards the tube. Occasionally, those

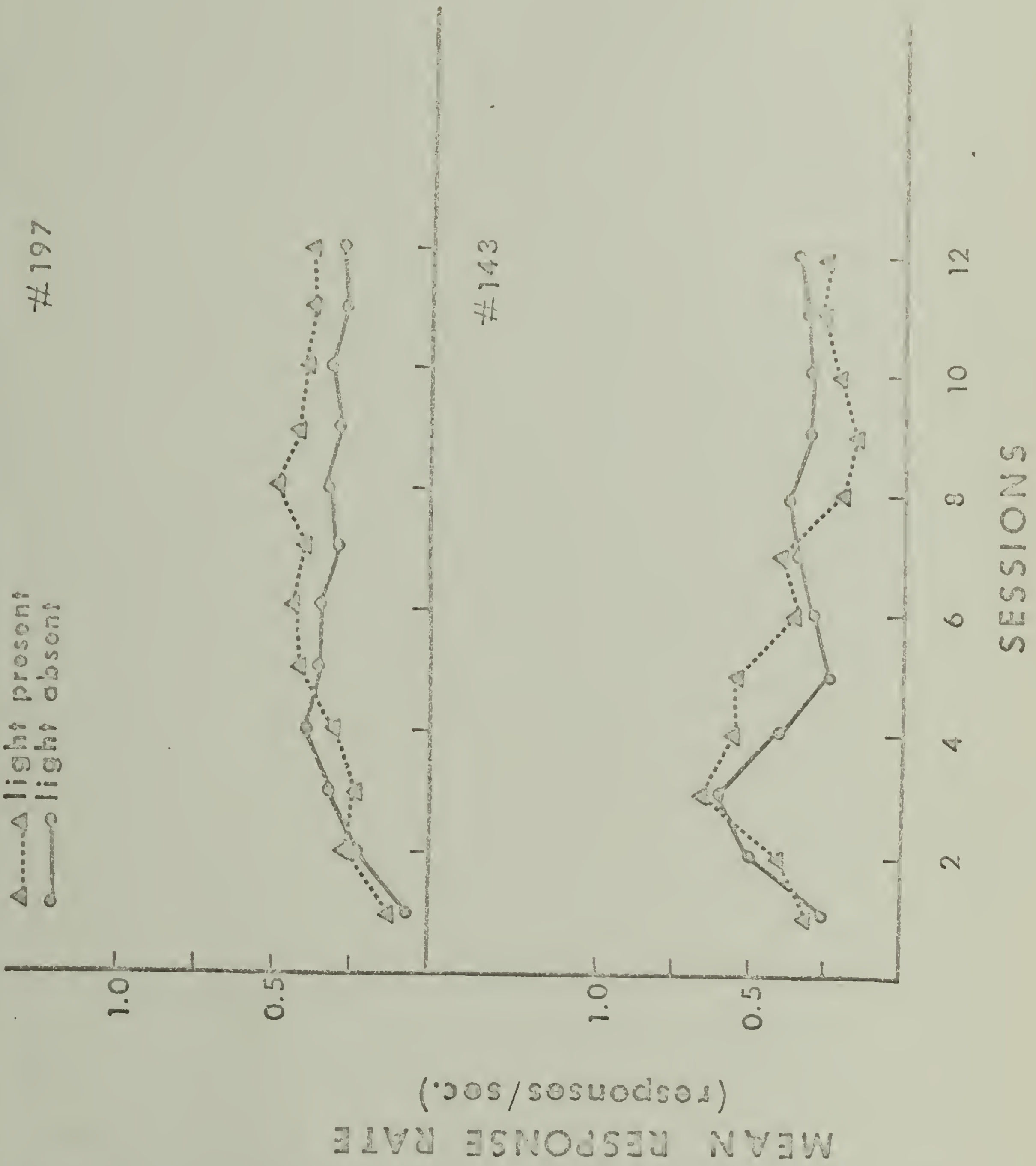

Figure 5. The mean rate of head-raising for each bird in Group 3 of Experiment 3. Both birds were exposed only to the mult (EXT)(mix EXT FI 8-sec)schedule of reinforcement. The triangles show the response rate during trials while the open circles show the response rate during the ITI.

orientations were followed by food and subsequently came to occur more often. Pecking occurred more often after orienting responses increased in frequency and so pecking at the tube may have occurred in part as a result of the differential reinforcement of orienting responses. All subjects other than bird 173 acquired pacing and head-raising responses in Phase 1, and the form of those responses varied within single birds as well as between different birds. Pecks at the key rarely occurred during Phase 1.

In Phase 2, when responses that interrupted the photo-beam were reinforced according to a mult EXT FI 8-sec schedule of reinforcement, responses came under control of the lighted key. Figure 6 shows the mean response rate in the presence and absence of the lighted key for each bird in all sessions of the experiment. The light did not control responding differentially during Phase 1. In Phase 2, the light came to control responding to a high degree for birds 173 and 187 and to a moderate degree for birds 193 and 194. The auditory feedback stimulus was added after session 27 in an attempt to bring the responding of the subjects (in particular, birds 193 and 194) under more precise control of the light. Just as for Group 1, the feedback stimulus had no systematic effect upon the behavior of the birds. When the feedback stimulus was added, there was an increase in the response rate in the presence of the light for birds 193 and 187 but not for birds 173 and 194. In Phase 2, bird

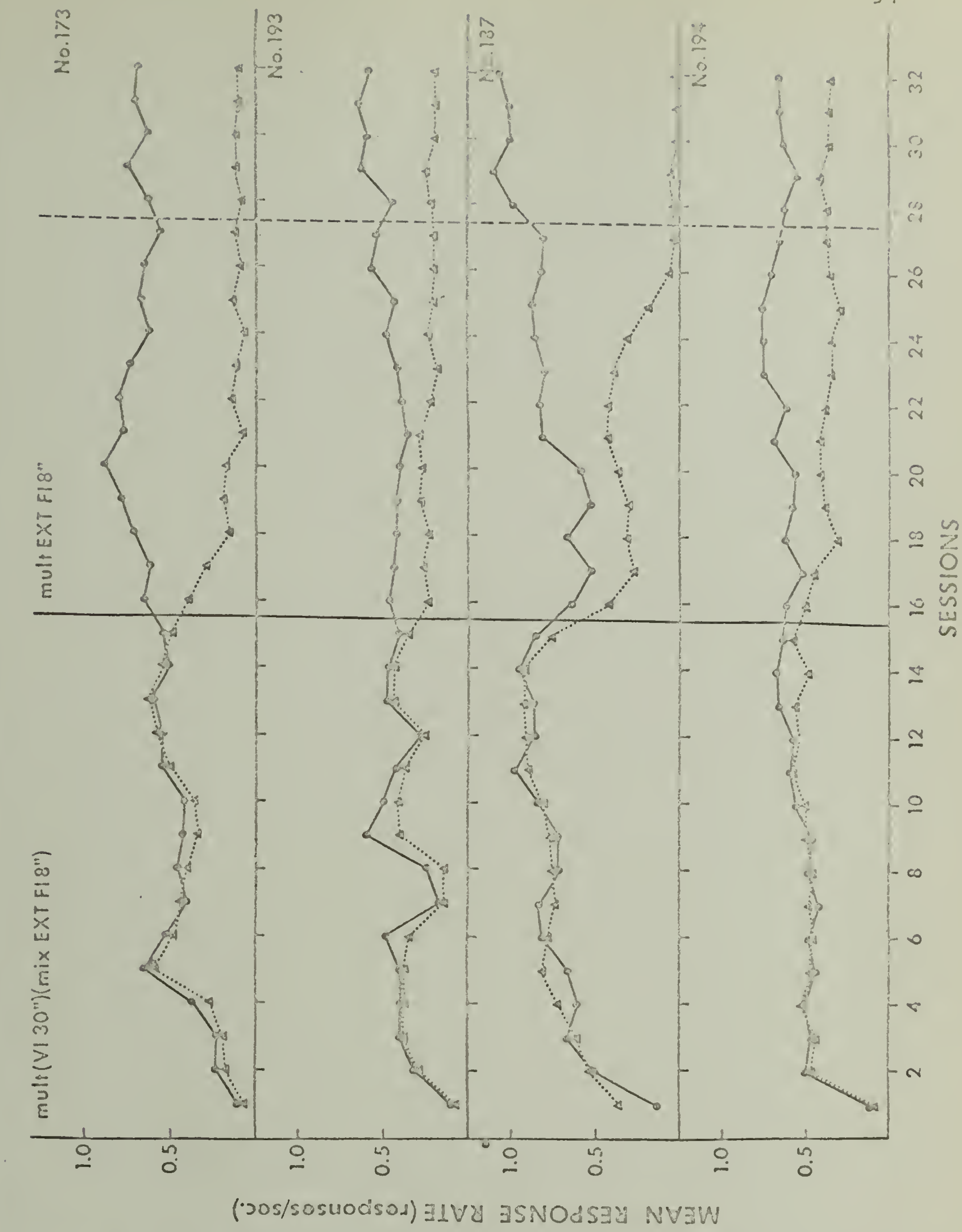

Figure 6. The mean rate of head-raising for each bird in Group 4 of Experiment 3. The broken vertical line indicates the point at which the feedback stimulus was introduced. The circles show the response rate during trials while the triangles show the rate during the ITI.

187 was the only subject in Group 4 that came to peck at the key reliably. Bird 187 rapidly emitted sequences of head-raises and pecks at the key, and pecks at the key became more frequent as the light came to control head-raises. Also, as bird 187 began to peck at the key, rapid nibbling and pecking responses were made as the head was raised. Many of the pecks at the key fell short of the key and were unrecorded. In order to measure the rate of pecking, five-minute portions of sessions 26 and 27 were recorded and pecking was scored by the experimenter. For bird 187, pecks at the key occurred at a mean rate of 0.53 responses per sec in the presence of the light while the rate in the absence of the light was 0.17 responses per sec. During Phase 2, bird 173 continued to peck at the tube as in Phase 1. Interestingly, the two birds that interrupted the photobeam by pecking were the same two birds whose behavior came to be highly controlled by the light. The birds whose behavior was moderately controlled by the light pecked infrequently during Phase 2. For the two birds in Group 4 that rarely emitted pecking responses, the light controlled nibbling responses and also occasional orientations to and approaches towards the light.

The behavior of the birds in Groups 4 and 1 differed in two major ways during Phase 2. Generally, the class of responses that had the effect of interrupting the photobeam came under sharper discriminative control of the light for the birds in Group 4 than for the birds in Group 1. Also, the light controlled pecks at the key for three of four birds in Group 1 but for only one of four birds in Group 4.

The differences in the behavior of the birds of Groups 1 and 4 during Phase 2 do not seem to be due to differences in the durations of the light and ITI during Phase 1. Table 6 shows the mean duration of the presence and absence of the light for each bird in Group 4 during Phases 1 and 2. A comparison of the data in Tables 4 and 6 shows that in Phase 1, the mean durations of the light and the ITI are similar for the birds in Groups 1 and 4. Table 6 shows that the mean durations of the ITI and the light for Group 4 remained fairly constant after the initial sessions of Phase 1. Since extended pauses in responding were infrequent, the duration of the light approached 8.0 sec and the duration of the ITI approached 30 sec.

The differences in the behaviors of the birds in Groups 1 and 4 during Phase 2 are not the result of differences in the response rates that occurred in Phase 1. A comparison of Figures 4 and 6 shows that the mean response rates for most birds in Groups 1 and 4 were between 0.50 per sec and 0.75 per sec during Phase 1. Also, there were no systematic differences in the topography of the responses that were conditioned in Phase 1 for the subjects in Groups 1 and 4.

The birds in Group 5 that were yoked to the birds in Group 4 behaved similiarly to the birds in Group 2 during Phase 1. Stereotyped pacing behaviors were conditioned for

TABLE 6

The mean duration of the trials and the intertrial intervals for each bird in Group 4 of Experiment 3. The corresponding yoked subject in Group 5 is shown in parentheses for each bird.

Session	bird 173(174)		bird 193(190)		bird 187(188)		bird 194(176)	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
1	8.0	34.8	8.2	37.4	9.4	29.9	10.6	32.1
2	8.0	28.3	8.9	31.2	8.5	29.4	8.5	29.3
3	8.4	32.3	8.4	29.9	8.1	29.1	8.3	29.5
4	8.9	31.9	8.2	29.6	8.4	28.9	8.4	28.8
5	8.3	29.3	9.2	29.2	8.2	28.4	8.4	30.7
6	8.4	29.2	8.4	29.8	8.3	29.0	8.2	28.6
7	8.4	28.8	9.1	35.9	8.2	28.9	8.4	28.8
8	8.3	30.5	8.4	39.8	8.2	29.0	8.4	29.0
9	8.3	30.3	8.4	29.4	8.5	28.9	8.2	26.8
10	8.4	29.1	8.3	28.5	9.8	28.6	8.1	28.5
11	8.4	28.6	8.4	28.7	8.1	28.2	8.1	28.8
12	8.3	28.4	8.7	30.7	8.7	28.4	8.2	28.7
13	8.3	28.1	8.3	29.3	8.2	28.8	8.2	29.7

TABLE 6 (cont'd.)

Session	bird 173(174)		bird 193(190)		bird 187(188)		bird 194(176)	
	trial	ITI	trial	ITI	trial	ITI	trial	ITI
14	8.3	28.5	8.4	29.2	8.3	29.9	8.2	29.7
15	8.3	28.4	8.3	29.2	8.1	29.1	8.2	29.1
16	8.9	30.9	9.5	30.9	9.2	30.9	8.9	30.9
17	9.8	30.9	9.5	30.9	9.0	30.9	9.1	30.9
18	8.7	30.9	9.2	30.9	8.6	30.9	8.7	30.9
19	8.6	30.9	9.3	30.9	8.9	30.9	8.7	30.9
20	8.4	30.9	8.9	30.9	9.3	30.9	9.0	30.9
21	8.4	30.9	9.3	30.9	8.8	30.9	9.1	30.9
22	8.4	30.9	9.0	30.9	8.9	30.9	9.1	30.9
23	8.3	30.9	9.6	30.9	8.2	30.9	9.2	30.9
24	8.4	30.9	9.8	30.9	8.9	30.9	8.9	30.9
25	8.5	30.9	10.0	30.9	8.9	30.9	8.5	30.9
26	8.4	30.9	9.1	30.9	8.8	30.9	9.1	30.9
27	8.4	30.9	9.4	30.9	8.6	30.9	10.2	30.9

TABLE 6 (cont'd.)

Session	bird 173(174)		bird 193(190)		bird 187(188)		bird 194(176)	
28	8.4	30.9	12.3	30.9	8.8	30.9	9.6	30.9
29	8.3	30.9	8.9	30.9	8.4	30.9	9.8	30.9
30	8.5	30.9	9.3	30.9	8.5	30.9	9.5	30.9
31	8.3	30.9	8.7	30.9	8.6	30.9	9.6	30.9
32	8.3	30.9	9.3	30.9	8.6	30.9	9.5	30.9

all birds in Group 5 and pecks at the key occurred infrequently. During Phase 1, birds 174, 190, 188 and 176 emitted 0, 0, 11, and 0 pecks at the key, respectively. During Phase 2, pecks at the lighted key occurred infrequently for all birds. The frequency of pecking for all birds except bird 174 is shown in Table 7. The data for bird 174 are not included in Table 7 since bird 174 pecked only once in Phase 2. Table 7 shows that the light did not control pecking for any bird in Group 5. However, the light did come to control nonpecking behavior for all birds in Group 5, and those nonpecking behaviors were similar to those that were controlled by the light for Group 2.

The major difference in the behavior of the birds in Groups 2 and 5 is that there was a high degree of behavioral variability for the birds in Group 2 at the start of Phase 2 while behavior did not become so variable for the birds in Group 5 at the start of Phase 2. The difference in the degree of behavioral variability may be due to the differences in the frequency of food presentation in Phase 2 for groups 2 and 5. The mean number of food presentations per session for Group 2 decreased from 63 in Phase 1 to 13 in Phase 2. For Group 5, the mean number of food presentations per session decreased from 63 in Phase 1 to 50 in Phase 2. Thus, there was a much smaller decrease in reinforcement frequency for Group 5 than for Group 2.

Of the three birds in Group 6 that were exposed only

TABLE 7

The mean rate of pecking during the trials and the intertrial intervals for the birds in Group 5 during Phase 2 of Experiment 3.

Session	bird 190		bird 188		bird 176	
	trial	ITI	trial	ITI	trial	ITI
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	.02	0	0	0	0	0
19	.02	0	0	.01	0	0
20	.02	0	.01	.01	0	0
21	.04	.01	0	0	.02	0
22	0	.01	0	0	.06	0
23	0	.01	0	0	.03	0
24	.01	.04	0	0	.04	0
25	.01	.08	0	0	.01	0
26	.02	.05	0	0	.01	0

to the mult (EXT) (mix EXT FI 8-sec) schedule of reinforcement, the behavior of bird 195 came to be highly controlled by the lighted key while the behavior of bird 198 was only moderately controlled by the light and the behavior of bird 196 was poorly controlled by the light. The mean rate of head-raising in the presence and absence of the light is shown for each bird in Figure 7. The differences between subjects and the extent of discriminative control of head-raising may be related to the topography of head-raising for different birds. For bird 195, the head-raises were almost always accompanied by binocular orientations towards the key and head-raising soon came to be controlled by the light. In contrast, head-raising for bird 196 was accompanied by frequent nibbling movements as the head was raised up and down a portion of the wall above the key. The nibbling movements did not come under control of the light and head-raises were seldom accompanied by binocular orientations towards the key. The lighted key appeared to control neither head-raises nor key-directed behaviors for bird 196. Bird 198 emitted sequences of approaches towards the key and raises of the head. Head-raising was frequently accompanied by nibbling movements. The head-raises of bird 198 started to come under control of the light when approaches towards the key came to be controlled by the light. Thus, the light occasioned approaches towards the light and raises of the head while the absence of the light occasioned head-raises alone. Pecks at the key occurred infrequently for all

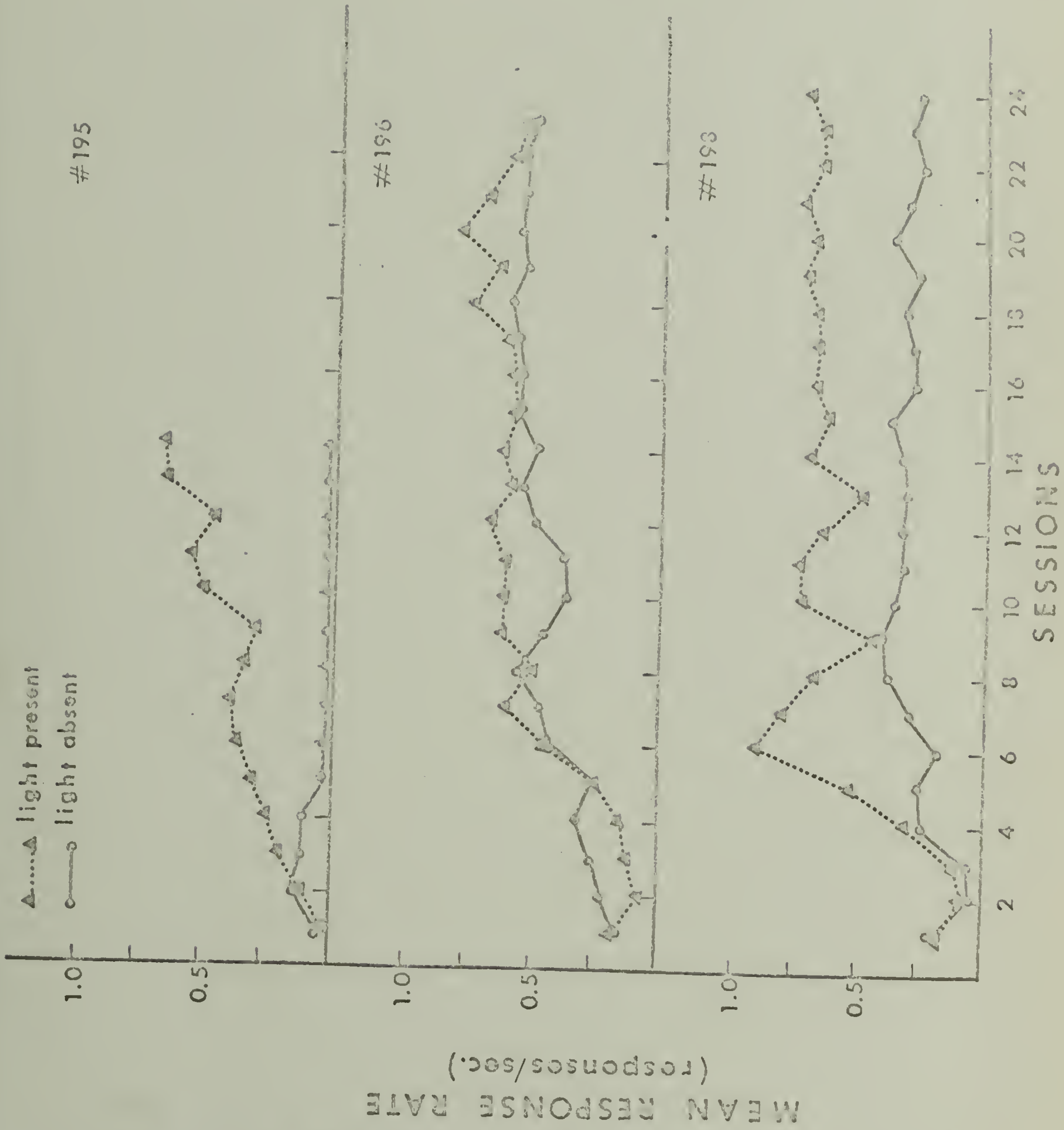

Figure 7. The mean rate of head-raising for each bird in Group 6 of Experiment 3. Each bird was exposed only to the mult EXT FI 8-sec schedule of reinforcement. The triangles show the response rate during trials while the circles show the response rate during the ITI.

birds in Group 6.

Following session 18, the auditory feedback stimulus was added for birds 196 and 198, but that feedback did not result in any large increase in the degree of discriminative control by the light. Also, there were no marked changes in the topography of the head-raises after the feedback stimulus was added.

Discussion

If the exposure to nondifferential light-food pairings results in the retardation of autoshaped pecking because of the conditioning of the responses that compete with pecking, then pecking should not have been conditioned during Phase 2 for Groups 1 and 4. Head-raising responses were explicitly reinforced in a situation where nondifferential light-food pairings were occurring. When the birds in Group 1 were subsequently exposed to a condition in which differential light-food pairings occurred but head-raises of some sort always preceded food presentation, pecks at the lighted key were conditioned for three of four birds. Thus, the head-raising responses that were conditioned when the light and food were paired nondifferentially did not compete with pecking responses when the differential light-food pairings occurred. In contrast, when the birds of Group 4 were subjected to a situation in which 100% light-food pairings occurred but head-raises always preceded food presentation, pecks at the lighted key were conditioned for only one of four birds. For most birds in Group 4, the class of responses that interrupted the photobeam may have competed with pecks at the lighted key. Generally, the results for Groups 1 and 4 do not unequivocally support or contradict the account of the retardation effect that is based upon the notion of response competition.

The question of most immediate importance for the interpretation of these results is why more pecking was emitted by the birds in Group 1 than the birds in Group 2. Stimulus-reinforcer variables were identical for those two groups, the frequency of food presentation was identical for both groups, and the behavior of the birds in both groups came to be controlled by the light. The following are two of the most plausible accounts of why the birds in Group 1 came to peck more frequently than the birds in Group 2.

The behaviors that were conditioned for the birds in Groups 1 and 2 during Phase 1 could have differed in significant ways. Perhaps it was more difficult to maintain the class of responses that interrupted the photobeam than the nonpecking responses that were maintained for the subjects of Group 2. Unlike the pacing responses of the birds in Group 2, the head-raising responses appeared to involve more effort. Also, in order to interrupt the photobeam, the birds were explicitly required to move away from the lighted key. If head-raises were more difficult to maintain than the nonpecking responses of the birds in Group 2, then head-raises might compete with pecking less effectively than other nonpecking responses might. However, this account is clearly post hoc in nature and so remains unconvincing until it is supported by the results of tests conducted in a situation that is independent of the present one.

The differences in the frequency of pecking for Groups 1 and 2 may be due to differences in the acquisition and maintenance of the nonpecking behaviors during Phase 1. For the birds in Groups 2 and 5, stereotyped pacing behaviors were observed to occur frequently after about 8 sessions in the nondifferential pairing condition. Since there were 15 sessions in Phase 1, there were about seven sessions in Phase 1 during which the conditioned responses occurred and were followed regularly by food. On the other hand, the birds in Groups 1 and 4 were trained during session 1 to raise their heads and so there were about 14 sessions in Phase 1 during which the conditioned responses were regularly followed by food. Since head-raises had been reinforced more extensively than pacing responses, it may seem that head-raising should have competed with pecking more effectively than the pacing responses. However, observation showed that the head-raising responses were more variable in form during the last three sessions of Phase 1 than were the pacing responses of the birds in Groups 2 and 5. The behavior of the birds in Group 1 appeared to become even more variable as a result of the decrease in the frequency of food presentations that occurred after the shift from Phase 1 to Phase 2. It may be that nonpecking responses will compete with pecking most effectively only when the nonpecking responses are very stereotyped. If so, then the nonpecking responses of the birds in Group 2 would have competed with pecking more effectively than the nonpecking responses of the birds in Group 1.

The latter account is consistent with the results of a pilot study in which pigeons were exposed to eight sessions like those of Phase 1, except that head-raises were scored by hand and were reinforced when the author operated the switch while observing the behavior. Head-raises were quite stereotyped during sessions five through eight. When the birds were then exposed to sessions like those of Phase 2, no pecking was acquired for either bird and the light came to control head-raising. From the results of the pilot study, it is unclear whether the retardation of pecking was due to the stereotypy of the head-raising responses or to the relatively short period of exposure to the mult (VI 30-sec) (mix EXT FI 8-sec) schedule. The stereotypy of the conditioned responses seems to be more important since head-raising competed more successfully with pecking for the birds in the pilot study than for the birds in Group 1 even though the class of responses that interrupted the photobeam for the birds in Group 1 had been reinforced more extensively.

One problem is common to both of the preceding accounts of the differences in the frequency of pecking of the birds in Groups 1 and 2. The problem is that for Group 1, responses that interrupted the photobeam were always followed most immediately by food presentation and it is perhaps unclear why pecking should have been maintained for the birds in Group 1. Even though head-raises were always followed by food most immediately, pecks were also followed by food after a short delay and the pecks may have been maintained due to the relationship between pecking and food ingestion in pigeons. One effect of contingencies of natural selection may have been to make pecking more easily associable with food under certain stimulus conditions than behaviors that do not belong to the repertoire of species-typical feeding behaviors in the pigeon. Alternately, since the pecking behavior of individual pigeons has often had the consequence of food ingestion, it may be that when both pecking and head-raising are followed by food, pecking will be reinforced to a greater degree than head-raising. The latter accounts are highly speculative but are consistent with the observation that for the birds in Group 1, pecking responses came to be controlled by the light and pecking seemed to compete with head-raising rather than vice versa. Furthermore, it seems unlikely that pecking was maintained as part of a chain of pecking and head-raising responses since the occurrence of pecking for bird 171 often delayed the presentation of food.

One of the least expected results of this experiment was that more pecking was conditioned for the birds in Group 1 than for the birds in Group 4. If pecking were generated by light-food pairings, then one would expect just the opposite result since the light was always paired with food for the birds in Group 4 while the light was paired with food intermittently for the birds in Group 1. The magnitude of the retardation of pecking appeared to be fairly similar for Groups 2 and 5 and so it seems unlikely that stimulus-reinforcer variables could account for the differences in the frequency of pecking for the birds in Groups 1 and 4. Also, the differences in pecking were not due to differences in the behavior-environment interactions that occurred in Phase 1. The behavior of the birds in Groups 1 and 4 were similar in Phase 1 and the lighted key and food were presented in the same manner for both groups. Finally, the occurrence of more pecking for the birds in Group 1 than for the birds in Group 4 was probably not due to the differences in the mean interval between light-food pairings for the two groups in Phase 2. If the longer intervals between pairings resulted in more conditioning of pecking, then the birds in Group 2 should have pecked much more often than the birds in Group 5 during Phase 2 (since the birds in Groups 2 and 5 were yoked to the birds in Groups 1 and 4, respectively). However, as described earlier, there were no substantial differences in the frequency of pecking for birds in Groups 2 and 5.

Most likely, the differences in the frequency of pecking for the birds in Groups 1 and 4 were due to the differences in the frequency of reinforcement for head-raising in those two groups. For the birds in Group 4, the frequency of reinforcement for head-raising during Phase 2 was almost four times greater than that for the birds in Group 1. If head-raises were more difficult to maintain than the nonpecking responses of the birds in Groups 2 and 5, then head-raises might have competed with pecking only if the head-raises were reinforced sufficiently often to be maintained. Alternately, the high frequency of reinforcement for head-raises for the birds in Group 4 may have resulted in less variable behavior for those birds during Phase 2. As discussed earlier, it may be that nonpecking responses will compete with pecking only if those responses are stereotyped.

Another unexpected result of this experiment was that there was sharper discriminative control of responses that interrupted the photobeam for the birds in Group 4 than for the birds in Group 1. Although the light did not come to control head-raising for the birds in Group 1, the light did control pecks at the key for three of four birds and the light controlled some type of key-directed behavior for all birds in Group 1. It appeared that the stimulus control of pecking for the birds in Group 1 resulted in the failure of the light to control head-raising. The responses of bird

191 that interrupted the photobeam came to be controlled by the light, but for that bird, interruptions of the photobeam occurred as the final movement of pecks at the key that were emitted from an upright position. The fact that the light came to control pecking but not head-raising for the birds in Group 1 is surprising because the light did come to control head-raising for the birds in Group 4. Since the light controlled head-raising for the birds in Group 4, it was clearly possible for head-raising to come to be controlled by the lighted key. Also, the light-food pairings did not make it impossible for responses other than pecking to be controlled by the light. Although the light-food pairings were more frequent and more consistent for Group 4 than for Group 1, the light came to control head-raises for Group 4 rather than for Group 1.

One plausible account of why the light controlled head-raising for the birds in Group 4 but not for the birds in Group 1 is that the frequency of reinforcement for head-raising in the presence of the light for Group 1 was too low for the maintenance of head-raises that would compete with pecking. If as the result of differences in the frequency of reinforcement, stereotyped head-raising responses occurred more often for the birds in Group 4 than for the birds in Group 1, then head-raising could have competed with pecking more effectively for the subjects in Group 4. The birds in Group 1 might have come to peck frequently as a result of the failure of head-raising to compete with pecking. When pecking occurred frequently, pecking came to be controlled by the light. The discriminative control of pecking by the light may have hindered the acquisition of stimulus control of head-raising for the birds in Group 1. In other words, the stimulus control of pecking may have blocked the acquisition of stimulus control of head-raising for the birds in Group 1. This account is also applicable to the results for the birds in Groups 3 and 6. For the birds in Group 3, key-directed behaviors began to occur frequently as the head-raising response was conditioned. The light came to control pecking behaviors for bird 197 and nibbling behavior for bird 143, but the light did not control head-raising for either subject. The control of key-directed behaviors by the light may have blocked the acquisition of stimulus control of head-raising. Also consistent with this account is the observation that the light controlled head-raising in two birds of Group 6. For both of those birds, behavior directed towards the light occurred frequently only after the light had acquired discriminative control of head-raising.

An alternative account of why head-raising was not controlled by the light for birds in Group 1 is simply that the schedules of reinforcement during the presence and absence of the light were insufficient for the acquisition of stimulus control of head-raising. More precise discriminative control of head-raising for Group 4 than for Group 1 could have resulted from the higher frequency of reinforcement for head-raising in the presence of the light for the birds in Group 4. The problem with this account is that the nonpecking responses of the birds in Groups 2 [illegible] 5 came to be controlled by the light despite the differences the frequency of food presentation in the presence of the light for those two groups. Also, the results of the pilot study that was described earlier show that under some conditions, head-raising may come to be controlled by a lighted key when a mult (EXT) (mix EXT FI 8-sec) schedule of reinforcement is in effect.

The differences in the behaviors that were controlled by the light for Groups 1 and 4 have implications for the view that behavioral contrast results from the same factors that are sufficient for the occurrence of autoshaping (Gamzu and Schwartz, 1973, in press; Hearst and Jenkins, in press). According to that view, behavioral contrast should occur primarily when two conditions are met. First, one must be studying a response that can be autoshaped by stimulus-reinforcer pairings. Second, some schedule of reinforcement (usually a multiple schedule) must be altered in such a way that one stimulus becomes differentially associated with reinforcement as a result of a change in schedule associated with another stimulus. For example, when one shifts from a mult VI 60-sec to a mult VI 60-sec EXT schedule, the stimulus that remains associated with the

VI 60-sec schedule (that stimulus will be called S1) becomes paired with the reinforcer in a differential manner. Thus, if pecking were the behavior being studied, the rate of pecking in the presence of S1 would increase following the change of schedule. Presumably, the additional pecking that occurs is generated by the differential pairing of S1 with the reinforcer in the same way that autoshaped pecking is presumed to be generated by differential light-food pairings (Gamzu and Williams, 1971, 1973).

The results of this experiment support the view that behavioral contrast and autoshaping have similar antecedents in that the first condition was not met and behavioral contrast did not occur with respect to head-raising. Interestingly, a small amount of behavioral contrast seems to have occurred for bird 191 in Group 1 and that bird was the only subject that combined head-raising movements with pecking movements. Another result that supports the latter account of behavioral contrast is that the differential light-food pairings for Group 1 resulted in the conditioning of pecking. However, the finding that pecking occurred less frequently for the birds in Group 4 than for the birds in Group 1 seems inconsistent with the view that the pecking of the birds in Group 1 was directly generated by differential light-food pairings. The light and food were paired more frequently and more consistently for the birds in Group 4 than for the birds in Group 1, and yet the birds in Group 4 came to peck much less frequently. In general, the results of this experiment do not unequivocally support or contradict the view that autoshaping and behavioral contrast have similar antecedents.

In conclusion, it is unclear from the results of this experiment as to whether the retardation of autoshaped pecking that occurs following exposure to nondifferential light-food pairings is due to the acquisition of responses that compete with pecking. The head-raising responses may have competed with pecking for the birds in Group 4 but head-raising clearly did not compete with pecking for the birds in Group 1. For the birds in Groups 2 and 5, the acquisition of pecking was retarded generally, and the light came to control variants of the responses that were conditioned during the exposure to nondifferential light-food pairings. It may be that the conditioning of stereotyped nonpecking behaviors is fortuitously correlated with the subsequent retardation of autoshaped pecking. However, that conclusion seems to be unwarranted at this time. In this experiment, there were differences in the nature of the nonpecking behaviors that were conditioned for the birds in the head-raising and the yoked conditions, and there were also differences in the acquisition and the maintenance of those behaviors. The results of this experiment could be due to the latter factors rather than the inadequacy of the account of the retardation effect that is based upon the notion of response competition. Additional experiments should be performed in order to test the adequacy of the account in terms of response competition.

In the future, it might be worthwhile to use other methods than that of this experiment to investigate whether the retardation effect results from response competition. For example, some of the problems inherent to the method of this experiment could be circumvented by studying the idiosyncratic behaviors that are conditioned in each subject as the result of nondifferential, response-independent pairings of a lighted key and food. One could test whether the retardation effect was due to response competition by exposing pigeons to a nondifferential pairing condition like that of Experiment II and then exposing the birds to a differential pairing condition in which food presentation is contingent upon the occurrence of the responses that were conditioned in the nondifferential pairing procedure. The responses could be defined and measured through rigorous observation. If in the differential pairing procedure, the light were to acquire control over the observed nonpecking (presumably) behaviors rather than pecking behaviors, then the retardation of pecking could be attributed to the acquisition of responses in the nondifferential procedure that compete with pecking.

GENERAL DISCUSSION

The results of these experiments have implications for a variety of accounts of the retardation of autoshaped pecking that occurs following exposure to nondifferential light-food pairings. In this section, an attempt will be made to specify the implications of the results of the preceding experiments for the accounts of the retardation effect in terms of (1) learned laziness, (2) the learning of a stimulus-reinforcer correlation, (3) attention, (4) response competition, and (5) control by concurrent stimuli.

According to an account of the retardation effect in terms of learned laziness, the birds in a nondifferential pairing condition discriminate the absence of a programmed response-reinforcer contingency. Presumably, pecking would subsequently be more difficult to autoshape since the birds had learned that food presentations occurred independently of either pecking or nonpecking behaviors. The account in terms of learned laziness is supported by some aspects of the results of Experiment III. For example, Groups 1 and 2 were exposed to similar nondifferential pairings of a lighted key and food, but food presentations were response-contingent for Group 1 and response-independent for Group 2. In the terminology of Engberg et al. (1971), the birds in Group 1 should have learned to be industrious while the birds in Group 2 should have learned to be lazy. Indeed, the birds in Group 1 came to peck at the lighted key more often than the birds in Group 2 (compare Table 3 and Table 5). However, there are many other aspects of the results of the preceding experiments that cannot be accounted for in terms of learned laziness. For example, since food presentations in Experiment III were response-contingent for the birds in Group 4 but not for the birds in Group 5, the birds in Group 4 should have come to peck more frequently than the birds in Group 5. In fact, the birds in Group 4 generally did not come to peck at the key more frequently than the birds in Group 5 (compare the description on page 98 with Table 7). Also, the results of Experiment II clearly contradict the account of the retardation effect in terms of learned laziness. The results of Experiment II showed that pacing behaviors that were vigorous and stereotyped were conditioned as a result of non-differential light-food pairings. Thus, there was no evidence that the birds actually discriminated the absence of a response-reinforcer contingency. In the subsequent differential pairing condition, pecking was retarded but nonpecking behaviors came to be controlled by the lighted key. Once again, there was no indication that the birds behaved as if there were no relation between responding and the presentation of food. Finally, the retardation of pecking that occurred in Phase 2 of Experiment I (see Figure 1) cannot be accounted for in terms of learned laziness. In general, the results of these experiments suggest that the retardation effect cannot be accounted for plausibly in terms of learned laziness.

According to Mackintosh (1973), the retardation of autoshaped pecking that results from nondifferential light-food pairings may be due to the birds having learned that there is no correlation between the occurrence of the CS and the presentation of food. The results of Experiment II decrease the plausibility of the account in terms of the learning of a stimulus-reinforcer correlation. If the birds learned in a nondifferential pairing condition that there was no correlation between the CS and food, then the acquisition of both pecking and nonpecking behaviors should be retarded in a subsequent differential pairing condition. However, the results of Experiment II (see Table 1) show that variants of the nonpecking behaviors that were conditioned in the nondifferential pairing procedure came to be controlled by the CS in the differential pairing procedure even if pecking occurred infrequently. Since the behavior of the subjects was clearly controlled by the light, the birds may be said to have learned something other than a zero correlation between the CS and food.

During exposure to a nondifferential pairing condition, the birds might have become inattentive to the lighted key since the light was not regularly paired with food. The subsequent retardation of pecking during the differential pairing condition might have resulted from a lack of attention to the key. The attentional account of the retardation effect is made tenuous by the observation that the lighted key did come to control the behavior of the birds during the differential pairing condition.

The results of the preceding experiments cannot be accounted for comprehensively either in terms of control by concurrent stimuli or in terms of response competition. However, the results of these experiments do not directly contradict the accounts in terms of response competition or control by concurrent stimuli. Unlike the accounts previously discussed in this section, the accounts in terms of response competition and control by concurrent stimuli may be consistent with the results of these experiments.

The results of Experiment I show that behaviors come to be directed towards those features of the environment in the presence of which the directed behaviors are differentially followed by food. When directed behaviors have come under the control of some environmental feature (S1), S1 will continue to control directed behaviors even in the presence of another stimulus (S2) in the presence of which directed behaviors are more consistenly followed by food. The latter result of Experiment I can be accounted for in terms of response competition as well as in terms of control by concurrent stimuli. That is, S2 may not come to control a high frequency of occurrence of directed behaviors since the responses controlled by S1 compete with the responses controlled by S2.

In Experiment II, nonpecking behaviors were conditioned when a lighted key and food were paired in a nondifferential manner, and variants of those nonpecking behaviors rather than pecking behaviors came to be controlled by the light when the light was subsequently paired with food in a differential manner. While it could be that the nonpecking behaviors competed with pecking behaviors, it is also possible that the directed behaviors were controlled both by the lighted key and by stimuli other than the lighted key. If orientations to features other than the key were followed by food only in the presence of the lighted key, then the lighted key may have exerted conditional stimulus control over orientations to other features in the environment.

In Experiment III, head-raising responses were explicitly reinforced first in a situation in which a lighted key and food were paired in a nondifferential manner and then in a situation in which a lighted key and food were paired in a differential manner. When the light was paired with food intermittently (Group 1), pecking came to occur frequently. When the light was always paired with food (Group 4), pecking generally did not come to occur at a high rate. Thus, the retardation of pecking that occurred after exposure to nondifferential light-food pairings may or may not have been due to the acquisition of head-raising responses that competed with pecking.

The results of Experiment III are no more easily accounted for in terms of control by concurrent stimuli than in terms of response competition. For the birds in Groups 1 and 4, orientations to a variety of stimuli were presumably conditioned during Phase 1. In Phase 2, orientations to stimuli other than the key could have been reinforced in the presence of the lighted key, and the directed behaviors of the birds in both groups could have come to be controlled by the light and stimuli other than the light. Yet the birds in Group 1 pecked at the light frequently while the birds in Group 4 did not. It may be that the orienting behaviors of the birds in Group 1 became more variable than those of the birds in Group 4 (for reasons discussed earlier) and so orientations to certain stimuli other than the light may not have been reliably followed by food. However, that account remains speculative until the antecedents of the differences in the behaviors of the birds in Groups 1 and 2 are clarified.

In general, the adequacy of either the account of the retardation effect in terms of control by concurrent stimuli or the account in terms of response competition cannot be decisively determined on the basis of the results of these experiments. However, it is possible in principle to discriminate between those accounts on the basis of experimental results. For example, one could subject pigeons to a nondifferential pairing condition in which a lighted key is the only aspect of the environment that could control visual orientations. If nondifferential light-food pairings result in the subsequent retardation of autoshaped pecking because of the conditioning of orientations to stimuli other than the light, then pecking should not be retarded when orientations occur only to the light in the nondifferential pairing procedure. One might prevent the occurrence of visual orientations to stimuli other than the lighted key by arranging the environment so that the chamber is dark in the absence of the light and so that the lighted key is very dim and localized. In such an environment, visual orientations could presumably occur only to the lighted key, but stereotyped nonpecking behaviors could be conditioned as the result of nondifferential light-food pairings. If pecking were not retarded following exposure to nondifferential light-food pairings in the latter type of situation, then one might attribute the retardation of pecking to the control of behavior by concurrent stimuli rather than the acquisition of responses that compete with pecking.

In practice, it is difficult for several reasons to arrange an environment such as the latter one in order to distinguish between the accounts in terms of control by concurrent stimuli and the account in terms of response competition. First, the autoshaping of pecking in pigeons does not occur unless the CS is highly localized (Wasserman, 1973), and in the absence of a houselight in the experimental chamber, pairings of a lighted key and food as in the experiments above do not result in the conditioning of pecking. In a pilot study by the author, this problem was circumvented by reducing the size of the light on the key to about 3mm and by operating the GE 44 bulb at about 4.5V dc rather than at 6V dc. When such a small, localized light was always paired with food in a dark chamber, pecking at the light was conditioned for 7 of 8 pigeons that were studied. However, another problem remains. That is, the effect of stimulus-reinforcer variables depends upon the nature of the CS that is used. In the pilot study described above, some birds were magazine trained in the dark chamber and were then exposed to a differential pairing condition in which every fourth CS on the average was paired with food. Although pecking was conditioned when the CS was always paired with food, pecking was not conditioned when every fourth CS was paired with food. It is unclear whether pecking was not conditioned as a result of the partial pairings, the decreased frequency of the pairings, or the decreased frequency of food presentation. Whatever the critical factors may be, since differential light-food pairings did not result in the conditioning of pecking, one may not ascertain the effects of nondifferential pairings of the small CS and food by exposing the subjects to differential pairings of the small CS and food.

On the basis of the results of the experiments described above, there does seem to be a way to distinguish between the account in terms of control by concurrent stimuli and the account in terms of response competition. Exposure to nondifferential light-food pairings retards pecking when pigeons are subsequently exposed to 100% light-food pairings. If that retardation were due to the conditioning of orienting responses to stimuli other than the light, then no retardation should occur as a result of nondifferential pairings of a small, localized light and food in a dark chamber. Thus, no retardation of pecking should occur in pigeons that are sequentially subjected to nondifferential and 100% pairings of a small, localized light and food in a dark chamber. Such a test should help to clarify the nature of the effects of nondifferential light-food pairings upon autoshaped pecking.

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