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HATTEN, ANNA DIXON

THE EFFECTS OF TEMPORAL AND SPATIAL LOCATION OF A CS PAIRED WITH FOOD ON A PIGEON'S KEY-PECK RESPONSE

The University of North Carolina at Greensboro PH.D. 1979

THE EFFECTS OF TEMPORAL AND SPATIAL LOCATION OF A CS PAIRED WITH FOOD ON A PIGEON'S KEY-PECK RESPONSE

by

Anna D. Hatten

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HATTEN, ANNA D. The Effects of Temporal and Spatial Location of a CS
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The effects of a classical conditioning procedure on behavior maintained by an operant schedule of reinforcement were studied. A Change in color associated with response-independent food was presented to pigeons at different temporal locations within a fixed interval between food presentations and at different spatial locations within the chamber. For two groups of subjects the food presented at the end of the fixed interval depended on a key peck on a schedule key, and for one group all food presentations were response independent. For the groups which received response-dependent reinforcement, both a simple fixed interval 60 sec schedule and a fixed interval schedule requiring low rates determined the baseline response rates for comparison with the response rates during the key-color change. The spatial location of the key-color change differed for the two response-independent reinforcement groups. For one group the change occurred on the schedule key and for the other group the change occurred on a separate signal key.

Response rates on the schedule key increased above baseline rates during the color change for all but one of the subjects experiencing response-dependent reinforcement. Larger increases in response rate were observed when the key-color change occurred early in the interval between food presentations than when it occurred late. The effects of the baseline schedule were more clearly seen in the rates of responding during the color change. Those rates increased as a function of the time of the onset of the change when the schedule was a simple fixed interval, but the rates were constant or decreasing functions of the time of the stimulus onset when the schedule required a low rate.

In addition, larger increases in rate were observed when the color change occurred on the schedule key. When all food presentations were response independent, pecking rates on the key on which the color changed were found to increase as a function of the temporal location of the color change for two of the three birds in this group. The results are discussed in terms of a classification system for operant-classical interaction procedures based on Staddon's (1972) discussion of such procedures.

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CHAPTER I

INTRODUCTION

While researchers generally agree that there are two procedures for conditioning behavior, an operant conditioning procedure and a classical conditioning procedure, there is less agreement about conditioning processes and their relationship to these procedures. According to some theories, there is only one conditioning process, and that process conditions the observed behavior regardless of the procedure employed. Other theories suggest that each procedure provides the prototype for a separate conditioning process. Many of the two-process theories additionally propose that the two processes are not independent. They note that the classical conditioning procedure is embedded in the operant procedure. The discriminative stimuli are paired with the reinforcer in operant conditioning just as the conditioned stimulus (CS) is paired with the unconditioned stimulus (US) in classical conditioning. Furthermore, they suggest that this embedded classical conditioning process may be influencing behavior generated by the operant process (Rescorla & Solomon, 1967). For example, some theorists have proposed that the classical process provides the motivation for the operant.

One outgrowth of the concern with the role of classical conditioning in operant conditioning has been a concern with the effects of classical procedures deliberately imposed during operant conditioning. This procedure may be termed the "operant-classical interaction" procedure. It was reasoned that, if embedded classical conditioning procedures were influencing operant behavior, then deliberately imposing a CS should have effects similar to those of the embedded CS, the discriminative stimulus. In this way the role of the CS in operant conditioning might be studied. One-process theorists have shown less interest in this procedure. If both procedures are assumed to exemplify the same process, then presenting a CS during operant conditioning would not differ theoretically from combining two classical conditioning or two operant conditioning procedures. The operant-classical interaction research, however, should be relevant to one-process theory because the results of such studies should be consistent with the theory's expectations derived from combining two classical or two operant procedures.

There are a number of theories which have proposed how a CS may affect operantly conditioned behavior. However, some data generated with operant-classical interaction procedures have been problematic for these theories. Two of these theories will be presented, together with the troublesome data.

One theory of operant-classical interactions, called the "expectancy" theory (Trapold & Overmier, 1972), focuses on the response-produced feedback of classically conditioned responses. In the operant conditioning procedure when the required response occurs, the discriminative stimulus is paired with the reinforcer. As a result, classically conditioned responses may become elicitable by the discriminative stimulus. The response-produced feedback of the classically conditioned responses then becomes part of the stimulus complex to which the operant is conditioned. If a CS, previously paired with an unconditioned stimulus, is presented together with the discriminative stimulus, then the response-produced feedback of the responses conditioned to the CS will occur together with the response-produced feedback of responses classically conditioned to the discriminative stimulus. The outcome of the procedure would depend, then, on the similarity of the conditioned responses elicited by the CS and discriminative stimulus. Expectancy theory proposes that the form of a classically conditioned response depends on the unconditioned stimulus used in the pairing procedure. If the reinforcer of the operant procedure is the same stimulus as the US of the classical procedure, then the responses conditioned to the CS and discriminative stimulus should be the same. As a result, presenting the CS and discriminative stimulus together should have the effect of increasing the amount of response-produced stimuli to which the operant is conditioned. The operant should consequently occur at a higher rate during the CS. If the US is different from the reinforcer, then response-produced stimuli of the responses conditioned to the CS should be different from those generated by the discriminative stimulus. As a result, the addition of the CS to the discriminative stimulus should function like the addition of any novel stimulus, and operant performance should be disrupted. The predictions of this theory, therefore, are: when the US and reinforcer are the same, operant responding during the CS should increase above levels observed in the absence of the CS; and, when the US and reinforcer are different, operant responding during the CS should decrease below levels observed in the absence of the CS. The data relevant to these predictions will be discussed after another theory of operant-classical interactions is discussed.

A second theory of operant-classical interactions is called the "motivational" theory (Millenson & de Villiers, 1972). According to the motivational theory, the pairing of a CS and US results in the conditioning of a motivational state relevant to the nature of the US. For example, if the US is food, the motivational state conditioned to the CS would be hunger. This classical conditioning procedure, therefore, is seen as providing the motivation for the operant. In the operant procedure the discriminative stimulus is paired with the reinforcer, and, consequently, a motivational state is conditioned to the discriminative stimulus which provides the motivation for the operant. When a CS, previously paired with a US, is presented together with the discriminative stimulus, the motivational states conditioned to the two stimuli interact. When the motivational state conditioned to the CS is the same as the one conditioned to the discriminative stimulus, the interaction is additive. The animal behaves, therefore, as though he is temporarily more motivated while the CS is present. When the motivational state conditioned to the CS is different from the one conditioned to the discriminative stimulus, the two motivational states inhibit each other, and the operant behavior is temporarily less motivated during the CS. The predictions of the motivational theory, therefore, are: when the cs and discriminative stimulus elicit the same motivational state, operant responding during the CS should increase above the levels observed in the absence of the CS; and, when the CS and discriminative stimulus elicit different motivational states, operant responding during the CS should decrease below levels observed in the absence of the CS. Because the nature of the motivational state depends on the nature of the US, the predictions of the expectancy and motivational theories are similar.

The data are consistent with the prediction that operant responding decreases when the US and reinforcer in operant-classical interactions are different (Rescorla & Solomon, 1967). Many studies, however, have found that responding during the CS decreases when the US and reinforcer are the same. Both the expectancy and the motivation theories would predict increases in responding during the CS.

The present research will focus on cases involving the presentation of a CS paired with an appetitive US during occasions for positively motivated behavior. Although this procedure has been called "positive conditioned suppression" by Azrin and Hake (1969), the results of the experiments have not been uniformly consistent with this title. Although suppression of operant responding often occurs during the CS (Azrin & Hake, 1969; Hake & Powell, 1970; Karpicke, Christoph, Peterson, & Hearst, 1977; Kelly, 1973a; Miczek & Grossman, 1971; Van Dyne, 1971), facilitation (Bower & Kaufman, 1963; Estes, 1943, 1948; Henton & Brady, 1970; Herrnstein and Morse, 1957; LoLordo, 1971; Meltzer & Hamm, 1974a, 1974b; Morse & Skinner, 1958; Osborne & Killeen, 1977; Shapiro & Miller, 1965; Walker, 1942), or both facilitation and suppression in the same experiment (Green & Rachlin, 1977; Kelly, 1973b; Lolordo, McMillan, & Riley, 1974; Meltzer & Brahlek, 1970; Schwartz, 1976; Smith, 1974) have also been observed.

One difference observed between experiments finding suppression and those finding facilitation has been the baseline response rate. Facilitation during the CS has been observed most often when baseline response rates have been low, whereas suppression has been observed most often when baseline response rates have been high. For example, of the experimenters reporting facilitation, Walker (1942), Estes (1943, 1948), Bower and Kaufman (1963), and Morse and Skinner (1958) presented the CS during extinction of the operant; and Shapiro and Miller (1965), Henton and Brady (1970), and Herrnstein and Morse (1957) presented the CS when low rates of responding were differentially reinforced. The experimenters reporting response suppression during the CS, in contrast, presented the CS when baseline responding was being maintained by a variable interval schedule, producing relatively high rates of responding. That the baseline response rate may be correlated with an important determiner of either suppression or facilitation of responding during a CS receives additional support from the findings of Kelly (1973b), Smith (1974), and Meltzer and Hamm (1974a). Kelly (1973b) found suppression when the CS was presented in a component of a multiple schedule maintaining a low rate of responding, a differential reinforcement of low rate schedule (DRL). Similarly, Smith (1974) found an effect of response rate when the CS was longer than 30 sec; high response rates were decreased during the CS, but low response rates were unaffected. Meltzer and Hamm (1974a), in addition, found that the amount of facilitation during the CS varied as a function of response rate. Manipulating the value of the variable interval schedule, they found more facilitation with schedule values providing a low rate of reinforcement and, hence, a lower response rate than with schedules generating a higher response rate.

The present study is concerned with quantifying some of the effects of presenting a CS paired with food during periods normally generating high, medium, and low response rates. As mentioned above, this problem has been studied before by Meltzer and Hamm (1974a) with rats, Kelly (1973b) with monkeys, and Smith (1974) with pigeons. Different response rates were generated either by changing the rate of reinforcement on a variable-interval schedule (Meltzer & Hamm, 1974a) or by changing the type of schedule studied (Kelly, 1973b; Smith, 1974). Such methods of varying response rate, however, are inappropriate for an attempt to quantify the effects of response rate on positive conditioned suppression performance, because changes in behavior due to the CS presentation can affect reinforcement deliveries provided by the baseline schedule. For each of the studies cited, the effects on reinforcement deliveries differed, depending on the condition employed to generate the high or low response rates. For example, in Meltzer and Hamm's (1974a) study in which rate of reinforcement was varied on a variable-interval schedule, suppression of responding during the CS would postpone the delivery of a scheduled reinforcer. As the rate of scheduled reinforcement increased, the "cost" in terms of reinforcers postponed by response suppression to a given level would also increase. The higher cost of response suppression during the CS should tend to reduce the suppression of responding during the CS. In Kelly's (1973b) and Smith's (1974) studies, response rate was varied by changing the schedule of reinforcement from a random ratio schedule to a DRL schedule. When the schedule is a random ratio, suppression of responding results in postponement of reinforcement, but facilitation results in decreased time to reinforcement. Conversely, on DRL schedules suppression of responding increases the rate of reinforcement, but facilitation of responding postpones reinforcement. Thus, the contingencies favor a reduction in facilitation when the baseline schedule is a DRL schedule and a reduction in suppression when the baseline schedule is a random ratio schedule. The obtained results were the opposite of these predictions, but though these procedures show the power of the effects of the CS, they are not good paradigms for studying the quantitative effects of response rate on positive conditioned suppression in more detail.

One control for the effects of changing response rates on reinforcement deliveries is to suspend the schedule of reinforcement during the CS presentation. Then changes in response rate during the CS can not effect reinforcement delivery. Suspending the schedule creates a different problem, however, because the subject can probably discriminate the signaled periods during which the schedule is suspended and will thus stop responding owing merely to the signaled absence of reinforcers.

The fixed-interval (FI) schedule of reinforcement provides an alternative way to vary response rate without suspending the schedule during the CS and without confounding response rate and reinforcement rate. On the FI schedule reinforcement is provided for the first response occurring after a fixed period of time since the last reinforcer, with earlier responses having no effect on reinforcement delivery. Response rate on the FI schedule is low after reinforcement and increases throughout the interval until the next reinforcement.

By presenting the CS at different times since food on a FI schedule, the effects of a CS on different baseline response rates may be assessed. Because reinforcers are unavailable during the interval, changes in response rate during the CS cannot affect reinforcement deliveries, and there is no need to suspend the schedule.

The fixed-interval schedule is also an interesting means for studying the effects of the relative proximity of the baseline reinforcer on positive conditioned suppression. Jenkins (1970), Staddon (1972), and Shull and Brownstein (1975) have suggested that the probability of responding or entering a response state increases at times near reinforcer presentation relative to the interreinforcement time. This notion has been termed the "relative proximity" principle, and the pattern of responding on fixed-interval schedules is representative of this principle. By presenting the CS at different times since food on a fixed-interval schedule, the effects of relative proximity to the baseline reinforcer on positive conditioned suppression may be observed; but, because responding varies with relative proximity to reinforcement on fixed-interval schedules, the effects of response rate _per se_ on positive conditioned suppression can not be separated from relative proximity effects. Farmer and Schoenfeld (1964), however, have reported that response rates during the interval may be reduced without changing the relative distribution of responding by adding constraints on the time between the reinforced response and the response immediately preceding it. This procedure, a "tandem fixed-interval DRL schedule," reinforces the first pair of responses spaced by some minimum time requirement after the fixed-interval has elapsed. The CS may be presented during the interval without changes in response rate affecting reinforcement deliveries and without suspending the schedule during the CS. If the CS is presented during the interval of the tandem schedule at relative proximity values corresponding to those studied with the fixed-interval schedule, comparisons between effects obtained with the two schedules may be made with relative proximity effects held constant but with differing baseline rates. Thus, the effects of two variables determining response rate, relative proximity and a rate contingency, may be compared.

Another possible determiner of positive conditioned suppression of interest in the present study relates to the nature of the CS and its relationship with the manipulandum for the operant. Karpicke, Christoph, Peterson, and Hearst, (1977), LoLordo, McMillan, and Riley (1974), Schwarts (1976), and Green and Rachlin (1977) have presented data suggesting that the location of the CS relative to the manipulandum is an important determiner of the effects of the CS-operant combination procedure. For example, Karpicke et al. (1977) have demonstrated with rats that the amount of suppression during a procedure involving a CS for food depended on the location of the CS relative to the manipulandum for the reinforced response. They trained two groups of rats to bar press for food. For one group the CS was the illumination of the response lever, and for the other group the CS was the illumination of a second lever. Response rates were suppressed during the CS only when it was located away from the operant lever.

Using pigeons, LoLordo et al. (1974) demonstrated that a CS located on the response key when the key is the manipulandum resulted in facilitation of responding during the CS. When the manipulandum was changed, so that the birds were required to treadle press for food, a CS located on the key resulted in suppression of treadle pressing. These results are consistent with Karpicke et al.'s (1977) findings. Although Karpicke et al. (1977) did not report facilitation of responding during the CS, the direction of the effect of CS proximity to the manipulandum was the same for both studies.

Schwartz (1976), also using pigeons and a key-peck response, replicated the findings of LoLordo et al. (1974) that a CS located on the response key results in response facilitation and that a CS located at a distance from the response key results in suppression of responding during the CS. In Schwarts's study, a single group of subjects was exposed to conditions in which the CS was either a change in light color on the response key or the illumination of a second key. When the CS was located on the second key, the subjects pecked the second key during the CS to such an extent that the sum of pecks on the second key and the response key during the CS was higher than the number of pecks observed in the absence of the CS. Thus, key pecking was facilitated during the CS, even though pecks to the response key were suppressed during these conditions. When the CS was a change in color on the response key, the rate of pecking the response key increased above baseline during the CS.

Finally, Green and Rachlin (1977) studied the effects of the location of the CS when the baseline was produced by a two-key concurrent variable-interval schedule of reinforcement. During baseline conditions, the variable-interval schedules associated with the two keys provided equal rates of reinforcement, and rates of responding on the two keys were approximately equal. The CS, a change in the color of the key light, could be presented on either key. Green and Rachlin (1977) found that responding during the CS increased on the key on which the CS was presented and decreased on the key on which the CS was not presented. This effect occurred despite the fact that food, the US, was delivered regardless of the location of the subjects' pecks. These findings suggest that the location of the CS is an important determiner of positive conditioned suppression effects.

LoLordo et al. (1974) and Schwartz (1976) investigated the effects of presenting an auditory CS that could not be localized. LoLordo et al. (1974) found inconsistent results when using an auditory stimulus. Some subjects' responding was suppressed by the CS, and other subjects' responding was facilitated. Schwartz found a slight amount of suppression of responding during the auditory CS for all subjects. Thus, only localizable stimuli such as a spot of light appear to have clear effects on positive conditioned suppression.

With procedures other than the positive conditioned suppression procedures, a reliable finding has been that animals will approach and contact a localizable stimulus paired with food delivery (see Hearst & Jenkins, 1974, and Schwartz & Gamzu, 1977, for reviews). Contact occurs even though it cancels food delivery (Williams & Williams, 1969). Thus, localizable stimuli paired with food may be viewed as having a directing effect on behavior, determining the location of an organism's interaction with the environment. When a CS is presented in the context of an operant conditioning procedure, the effects would depend on the location of the CS relative to the operant manipulandum. Facilitation of responding during the CS should result when the CS is located on or close to the manipulandum so that approaching or contacting the CS would result in switch closures that would count as responses. Suppression should result when the CS is located at a distance from the manipulandum, so that approaching the CS takes the animal away from the manipulandum. Nonlocalized stimuli, such as tones paired with food, may elicit responses which can be executed simultaneously with the operant without affecting the rate of the operant response. Thus, the nature of the CS and its relationship to the US is held to determine the nature of the behavior conditioned to the CS, and the nature of the conditioned response determines the positive conditioned suppression effect.

As mentioned previously, more traditional views of positive conditioned suppression have suggested that the presentation of a stimulus paired with food results in heightened motivation or perhaps increased expectancies of food. According to those views, responding during the CS should always be enhanced either by the increased motivation for that operant or by the inclusion of additional stimuli to which the operant is conditioned. These views alone, however, do not account for cases in which responding is suppressed during the CS when the US and operant reinforcer are the same.

Alternatively, positive conditioned suppression may be viewed as the result of changes in the relative rate of reinforcement for the measured operant. A substantial amount of data have shown that the rate of responding for a particular operant is an increasing function of the rate of reinforcement provided for that operant and a decreasing function of the rate of reinforcement provided for all other behavior (Catania, 1963; Herrnstein, 1970; Rachlin & Baum, 1972). This rate-decreasing effect of alternative sources of reinforcement has been demonstrated when the alternative reinforcement is unsignaled and response independent (Rachlin & Baum, 1972). Thus, in the positive conditioned suppression procedure, the addition of the response-independent food at the termination of the CS would serve to increase the rate of reinforcement for alternative behavior relative to that provided for the measured operant during the CS. This circumstance would predict a decreasing rate of measured responding during the CS. As mentioned earlier, however, sometimes enhanced responding is observed during the CS in positive conditioned suppression procedures. Thus, only when the location of the CS is considered may the enhancement and suppression of responding during the CS be explained.

The present experiment investigated the effects of variables producing changes in baseline response rate on positive conditioned suppression under three conditions. For one group of pigeons, the CS was a change in the key color on the schedule key, the schedule key being the one on which responding was required for reinforcement; for a second group, the CS was a change in the color of a second key, one different from the schedule key; and, for a third group, the CS was presented on a key, but there was no response requirement for food on the baseline schedule. Thus, the effects of the temporal location of the CS and the effects of the different baseline schedules were studied under conditions in which the location of the CS would favor either suppression or facilitation of responding on the schedule key during the CS; furthermore, the study provided opportunities to study the effects of the temporal location of the CS and the rate requirements of the baseline schedule on response rate to the separate signal key. The third group provided an opportunity to study the effect of temporal location of the CS on responding when there was no competing response required by the baseline schedule.

In an attempt to clarify the effects of certain variables on positive conditioned suppression it would be useful to develop a classification scheme which provides both a rationale for catagorizing independent variables aside from their effect on response rate during the CS and a means for predicting the effects of each variable on responding during the CS. The following is an attempt to develop such a classification. First a rationale is provided for chosing a particular scheme, and then in Chapter IV the scheme will be applied to the data of the present experiment to determine whether the classification has any predictive merit.

Staddon and Simmelhag (1971) and Staddon (1972) have proposed a conceptualization of conditioning which provides a framework accomodating the independent variables effective in positive conditioned suppression procedures. According to their account, conditioning involves two types of processes: generative processes, which operate according to the Principles of Variation; and a selective process called the Principle of Selection. In their theory all behavior in a given situation is generated according to the Principles of Variation, and when stimuli which may serve as reinforcers or US's are presented noncontingently, the Principles of Variation act alone to determine the observed behavior. The Principle of Selection operates only when a contingency is programmed, and Staddon and Simmelhag (1971) suggest that the contingency serves to direct the behavior generated by the Principles of Variation. For example, Staddon and Simmelhag observed that pigeons placed on a periodic schedule of food delivery tended to peck the front panel of the chamber just prior to food delivery whether or not food was contingent on pecking. Thus, pecking may be viewed as due to the Principles of Variation. When food was made contingent upon pecking a lighted response key on the front panel, the pigeons began to restrict their pecks to the key. Thus, the response contingency appeared to select from the responses available as a result of the Principles of Variation. The Principle of Selection directed the available behavior towards the lighted key.

When reinforcing stimuli are presented periodically, the activities produced by the Principles of Variation may be divided into two categories: terminal activities, occurring when the probability of reinforcement is high; and interim activities, occurring when the probability of reinforcement is low. Selective processes affect only the terminal activities. When reinforcers are delivered independently of responses, both of these types of activities occur unmodified by the Principle of Selection. When reinforcement depends on a response, however, terminal activities which conform to the response requirement continue to occur. Interim activities remain unchanged by the contingency.

Although the Principles of Variation and the Principle of Selection determine the form or topography of observed behavior in a given context, reinforcement scheduling variables are viewed as determining the proportion of behavior devoted to terminal activities and the temporal placement of terminal activity. Reinforcement scheduling may be viewed as operating according to two principles, the Relative Frequency Principle and the Relative Proximity Principle (Staddon, 1972). According to the Relative Frequency Principle, the amount of terminal activity controlled by a given stimulus is determined by the frequency of reinforcement provided in the presence of that stimulus relative to the frequency of reinforcement provided in the absence of the stimulus. According to the Relative Proximity Principle, the likelihood of observing terminal activities at a given point in time depends on the relative proximity of that point in time to the next reinforcer presentation. Similarly, stimuli occurring at a given point in time will control terminal activities depending on the relative proximity of the stimulus presentation to reinforcement.

Staddon (1972) has also suggested that, once terminal activity has commenced, the form of the activity may be affected by the relative frequency or proximity of reinforcement. Topographies associated with the highest relative frequency or proximity of reinforcement will tend to predominate. Also behavior appropriate to a particular stimulus will predominate over behavior appropriate to other simultaneously available stimuli when the stimulus is associated with higher frequencies or proximities of reinforcement. The form of the terminal activity will be affected by the rate and delay of reinforcement when different forms, or stimuli controlling different forms are associated with different rates and delays of reinforcement. The rate or delay of reinforcement achieved by adjusting response topography, however, will determine the distribution of behavior between terminal and interim activities.

This conceptualization of conditioning allows independent variables to be divided into two broad classifications: variables which determine the topography of behavior, called shaping or directing variables; and variables which determine the likelihood of observing terminal activities. When the terminal activity in a given situation is composed of a single activity differentially reinforced by the experimenter, then variables which determine the likelihood of observing terminal activities are often considered to be response strengthening variables. In Staddon and Simmelhag's view, however, terminal activity may consist of responses other than the one explicitly reinforced. For this reason and because interim and terminal activities are often considered to be associated with different motivational states, variables which determine the likelihood of observing terminal activities will be called motivational variables. Directing variables would consist of any contingency selected for particular response topographies or any situation in which the Principles of Variation generated a particular topography. Motivational variables would consist of scheduling variables such as the observed rate and delay of reinforcement regardless of the presence of a response contingency. If this classification system is to be useful, the variables affecting positive conditioned suppression should be readily classifiable according to this scheme.

As mentioned earlier, several variables have been found to affect positive conditioned suppression in consistent ways. Two of these which are relevant to the present research are the baseline response rate and the location of the CS relative to the operant manipulandum. Response rates during the CS have been found to decrease as a function of the baseline response rate and to decrease when the CS is located at a distance from the operant manipulandum.

Because the function relating baseline response rate and response rate during the CS is a statement of relations between two dependent variables, the variable baseline response rate is not readily classifiable according to this scheme. A statement of the independent variables employed to vary the baseline response rate must be given. Several methods for varying baseline response rate are available.

One method for varying baseline response rate involves manipulating delay, rate, or amount of reinforcement. This method has been employed by Meltzer and Hamm (1974a), who varied the rate of reinforcement provided for the baseline response; and by the present study, which varied the temporal placement of the CS in a fixed interval between food presentations, thereby varying the delay of the baseline reinforcer at the time of the CS presentation. These would represent motivational variables in the present scheme, and they would therefore be expected to affect the amount of terminal behavior generated by the schedule of reinforcement.

Other methods of varying the baseline response rate involve changing the relationship between response rate and the frequency of reinforcement. Examples of this type of manipulation would be the use of such schedules of reinforcement as the random ratio schedule in which high rates of responding can increase the rate of reinforcement and DRL schedules in which lowered rates of responding increase the rate of reinforcement. Examples of studies employing this type of rate manipulation are the studies reported by Kelly (1973b) and Smith (1974) and the present study, which employed a rate contingency in tandem with the fixed-interval schedule of reinforcement. Because the rate change is accomplished by making reinforcement contingent on a particular rate of responding and response requirement may only affect the topography and not the amount of terminal activity, these manipulations would be examples of directing variables. Thus, in the present study the addition of the pacing contingency should affect responding during the CS only by varying the topography of terminal behavior.

The location of the CS relative to the operant manipulandum is readily classified as an example of a directing variable. This variable should have no effect on the rate, delay, or amount of reinforcement, and therefore, should not affect the amount of terminal behavior. Further, it has been noted that even in the absence of response contingencies, pigeons tend to approach and peck localizable stimuli paired with food. Thus, the location of the CS should have effects on behavior during the CS that are consistent with this robust Principle of Variation (see Schwartz & Gamzu, 1977 and Hearst & Jenkins, 1974 for reviews concerning this phenomenon).

CHAPTER II

METHOD

Subjects

The subjects were ten male Silver King pigeons maintained at approximately 80 percent of their free-feeding weights.

Apparatus

The experimental space consisted of a rectangular chamber 52 cm by 40.6 cm by 38.5 cm enclosed in a wooden box. The chamber was equipped with a speaker for presenting masking noise, a relay for providing a response feedback click, two response keys (1.5 cm in diameter, operated by a force exceeding approximately 10 gm), a houselight, and a Lehigh Valley grain dispenser. The opening for grain presentations was located in the center of the front (40.6 by 38.5 cm) panel 11 cm above the floor. The response keys, also located on the front panel, were 23.5 cm from the floor with one in the center of the panel directly above the grain dispenser and the other 8 cm to the left of the center key. Both keys could be illuminated from behind by a white, a red, a blue or a green circle of light 0.5 cm in diameter in the center of the key. The illumination of only a small circle in the center of the key served two purposes. First, LoLordo et al. (1974) reported that their birds pecked frequently around the key without closing the switch. Thus, behavior generated by their response-independent procedure was often not recorded even though it was directed toward an area near the CS. With the small stimulus located on the key, however, pecks around the edge of the circle of light would be more likely to be recorded. In addition, pilot data collected in the experimental chamber employed in this study had indicated that the small lighted stimulus resulted in more pecking movements toward the key than did the illumination of the whole key.

Procedure

In outline, the procedure consisted of three phases: a classical conditioning phase; an operant baseline training phase in which food was presented at fixed intervals, either contingently on responding or not; and a phase during which the CS-US pair was presented while the baseline schedule was in effect. For the combination procedure the temporal location of the CS-US pair in the fixed interval was varied between blocks of sessions. The subjects were divided into three groups corresponding to the relationship between the CS location and the response requirement. For the same-key group, consisting of three subjects, the CS and key-peck requirement were located on the same key. For the different-key group, consisting of four subjects, the CS and key-peck requirement were located on different keys. For the FI group, consisting of three subjects, there was no key-peck requirement and the CS was presented on the left-hand key in the chamber. Table 1 presents the conditions for each subject in the order in which they were studied and the number of sessions for each condition.

All sessions were initiated by the onset of a houselight and the illumination of the two response keys. All food presentations were accompanied by the offset of the key lights and the houselight and the onset of a hopper light. All hopper presentations were 4 sec in duration.

Following hopper training, all subjects were exposed to a Pavlovian delay conditioning procedure. Each session consisted of 40 presentations of a three component cycle: a 54 sec intertrial interval; a 6 sec CS presentation; and a 4 sec grain presentation. The inter-trial-interval stimulus was illumination of both response keys by white lights, and the CS was a key-light color change to red on the left-hand response key. The center key remained white during the CS. Pecks were recorded during this phase of the experiment, but pecks had no effect on food delivery. The procedure was continued until pecks were recorded on the left-hand response key for 90 percent of the CS presentations in a session, or until 10 training sessions were completed, whichever came first. All birds except D-1 met the criterion of 90 percent.

Following classical-conditioning training, the baseline conditioning phase was begun. For all subjects the response keys were lighted green, and pecks to the left-hand key were recorded. For the same- and different-key groups, subjects were hand-shaped to peck the left-hand key, the schedule key; and for those subjects a feedback click followed each peck to the key. Pecks to the center key had no consequence for any of the subjects. Following shaping, the same- and different-key groups were trained to respond on a fixed interval (FI) 60 sec schedule of reinforcement, and the FT group was exposed to a fixed time (FT) 60 sec schedule of reinforcement in which the hopper was operated 60 sec after the previous hopper presentation regardless of the birds' behavior. For all groups the session continued until 40 intervals were completed. This phase was continued for approximately 30 days, until the response rates and postreinforcement pauses were stable.

After baseline training, the CS-US pair was presented during the fixed interval for all groups. The CS was always a change in the color of the appropriate key from green to red, 6 sec in duration, followed by a 4 sec hopper presentation. For the FT- and same-key groups the CS was presented on the left-hand key, which was the schedule key for the groups with the FI baseline; for the different-key group the CS was presented on the center key. For a series of sessions the onset of the CS was always at a fixed time since the preceding baseline reinforcer; the time of the onset was varied across sessions for all subjects in the following order: 48, 24, 0, 24, 48, and 0 sec since reinforcement. Within a session the CS-US pair was presented during every fourth interval, and sessions continued until the subject had completed 40 fixed intervals. Thus, there were 10 CS-US presentations during each session. The intervals of the baseline schedule were not restarted by the food signaled by the CS.

Next, a tandem fixed-interval 60-sec DRL 4-sec baseline schedule (FI-DRL) was put into effect for the same- and different-key groups. Reinforcement followed the first pair of responses spaced by 4 sec after 60 sec had elapsed since the last reinforcer presentation. Farmer and Schoenfeld (1964) have found that this schedule results in reduced response rates while preserving the overall pattern of responding typically generated by fixed interval schedules.

After performance on this schedule had stabilized, the CS-US pair was again presented during every fourth fixed interval. The time of CS onset was varied across blocks of sessions in the following order: 0, 24, and 48 sec since the previous fixed interval reinforcer. In all respects other than the pacing contingency the conditions were identical to those in which the CS-US pair was presented during the fixed interval 60 sec schedule. At the conclusion of this phase of the experiment one of the three subjects in the same-key group, S-3, became ill and was discarded from the experiment.

Next, for all groups a truly random control classical conditioning procedure was presented (see Rescorla, 1967). The left-hand key was illuminated by a blue light for 6 sec alternating with a white light for 54 sec. The center key was always illuminated by a white light. Independently of the key-light color and the birds' behavior, the hopper was operated on a variable interval 60 sec schedule programmed by a film tape reader. Each session was terminated after 40 hopper presentations, and the birds were exposed to this procedure for two days. The purpose of this truly random control procedure is to prevent responses conditioned to the CS from generalizing to the CS^0 of the control procedure.

After training with the truly random control procedure for classical conditioning, the same- and different-key groups were again trained on the FI 60 sec schedule, and the FT group was trained on the FT 60 sec schedule. Both keys were lighted green during the retraining phase, which continued until performance was stable.

After baseline retraining, the blue light (CS^o) was presented during every fourth fixed interval, and the time of the CS^o onset was varied across blocks of sessions in the following order: 0, 24, 48 sec since the previous fixed interval reinforcer. Except for the omission of the hopper presentation at the end of the CS, these conditions were identical to those conditions in which the CS-US pair were presented during the fixed interval. Presentations of the CS^o during the fixed intervals allowed comparisons to be made between conditions during which a stimulus was presented at various times in a fixed interval with conditions during which a CS-US pair was presented. The CS^o alone procedure is not intended to assess the effects of the CS-US pairing in the operant-classical interactions.

Presumably, the blue light is being paired here only with the baseline reinforcer, and the effects of the US are being factored out. The control procedure may not be viewed, however, as a control for the effects of all pairings of the blue light with food. To accomplish this the blue light would have to be presented uncorrelated with food while the pigeons were responding with the fixed-interval schedule in effect. Because the CS could not be presented at a fixed time in the fixed interval without there being a relationship between the CS and food, this procedure was not attempted. The alternative to using an uncorrelated classical procedure on baseline would be to continue the uncorrelated procedure off-baseline, and then probe the baseline conditions with the CS^o. This would involve comparing on-baseline CS-US pairing with an off-baseline truly random control procedure. Because the effects of truly random controls have been so effectively demonstrated in other contexts (Rescorla, 1967), this procedure was not included in the present research.

Finally, control conditions were instituted to determine the effects of the US presented at comparable times in the fixed intervals without its being preceded by a key-color change. The time of the US onset was varied across blocks of sessions in the following order: 6, 30, and 54 sec since the previous fixed interval reinforcer. These US onset times were the same as the US onset times in conditions in which the CS-US pair was presented, and measures of behavior were taken as though a stimulus had preceded the US for 6 sec. The results of this condition would indicate whether the subjects had been anticipating the CS-US pair by "counting" intervals between CS-US pair presentations.

In operant-classical interaction procedures, responding during the CS is typically compared with responding during a control period equal in duration to the CS period and immediately preceding the CS. Fixed interval schedules, however, generate differences in responding as a function of time since the last reinforcer presentation, and changes in behavior observed during consecutive time periods would be expected even in the absence of a CS. Thus, the appropriate control measures on fixed interval schedules should be taken in a second fixed interval at a time comparable to the time of the CS onset. In the present experiment, the CS's were presented for all groups in 10 of the 40 intervals in a session, and control measures were taken in 10 additional intervals in the session. These control periods, 6 sec in duration, occurred at the same time since the previous reinforcer in the second interval after the interval during which a CS-US pair, CS^o, or US was presented.

CHAPTER III

RESULTS

Fixed Interval and Fixed Time Baseline Conditions

The data of interest were rates of responding during the CS as compared with rates of responding during a control period in which measures were taken in the absence of a stimulus change. Figure 1 presents relative measures of response rates on the schedule key for conditions in which responding was maintained by a fixed-interval 60 sec schedule. The results are expressed in terms of a ratio of response rates during the CS to the sum of response rates during the CS and control periods, and they are plotted as a function of the temporal location of the CS in the fixed interval. For this measure, often called a "suppression ratio," a value of 0.5 indicates no difference between response rates during the CS and control periods, 0 indicates complete suppression of responding during the CS, and 1.0 indicates a maximum of facilitation of responding during the CS. No data are shown with this measure for the FT group because baseline responding was so low that all suppression ratios would have been approximately 1.0.

Two effects are of interest in this figure: the effect of the temporal location of the CS in the interfood interval; and the effect of the spatial location of the CS. As the CS was presented later in the interval, the suppression ratios declined for all birds except for D-3 and the first determination for D-4. The ratios for D-3 were flat or perhaps slightly increasing as a function of the temporal location of the CS. The exception was the 0 sec recovery condition in which the absence of any response during the control period forced the point to 1.0.

Comparisons between the groups showed that in most cases the suppression ratios were above 0.5 regardless of the spatial location of the CS. This indicates that responding for both groups increased over control rates during the CS. The data for D-3, for which the signal appeared on the other key, was the only consistent exception to that finding. Differences between the groups appeared only when the CS was presented in the middle or later half of the interval. When the CS was located at a distance from the schedule key, the value of the suppression ratio was depressed late in the interval as compared to ratios obtained at the same time in the interval for the subjects for which the CS was presented on the response key. This finding is consistent with the notion that a CS located at a distance from the manipulandum may interfere with the amount of responding that would have occurred with a CS located near the manipulandum.

Although the suppression ratios in Figure 1 show changes in schedule-key response rate during the CS relative to control rates, they obscure information about absolute changes in rate as a function of the temporal placement of the CS in the fixed interval. Response rates during the CS could be increasing, decreasing, or flat functions of the temporal location of the CS and still result in a declining suppression ratios as long as the control rates increased sufficiently. Figure 2 presents average schedule-key response rates during the CS and control periods for each temporal placement of the CS in the fixed interval and fixed time conditions. Birds S-1, S-2, and S-3 received the CS on the schedule key, birds D-1, D-2, D-3, and D-4 received the CS on a separate signal key and birds I-1, I-2, and I-3 were never required to respond for food. For each of the fixed-interval schedule birds, the same- and different-key groups, response rates during the control period increased as a function of time in the interval. For the fixed-time schedule birds, the FT group, the small amount of responding that did occur during the control period also increased as a function of the temporal location of the control period in the interfood interval. These are typical response patterns for the respective types of baseline schedule.

Response rates on the schedule key during the CS were higher than control rates for all birds in the same-key and FT groups and for most of the birds in the different-key group. The data for D-3 and the 24 and 48 sec first determination conditions for D-2 were exceptions. Similar information was conveyed by the suppression ratios greater than 0.5 shown in Figure 1.

Between-group differences and differences for different temporal locations of the CS in schedule-key pecking during the CS are also shown in Figure 2. The birds in the same-key group pecked the schedule key at a higher rate than did the birds in the FT and different-key groups, and the birds in the FT group pecked the schedule key at a higher rate than did the birds in the different-key group. Within each group the rates of schedule-key pecking may be characterized as increasing as a function of the temporal location of the CS within the fixed interval. There were some reversals and some striking exceptions. The exceptions were the first set of conditions for bird D-2 and all conditions for bird I-3. In both of these cases, the birds pecked the schedule key during the CS at decreasing rates as the CS was presented later in the interval. For D-2 this result was probably an acquisition effect. For the first three conditions studied with this bird, responding increased with the order of the conditions.

In order to assess the reliability of the results, an analysis of variance was performed using each subject's schedule-key response rate during the CS averaged for the original and replication of each temporal location of the CS. The results of this analysis are presented in Table 2. Both the differences between the groups and between the temporal locations of the CS were significant ($\alpha = .01$). These differences are important because they show that both the spatial and temporal location of the CS are determiners of responding during the CS, and such a finding is consistent with the results of previous studies cited in Chapter 1.

Because some theories of operant-classical interaction effects attribute them to the interference of behavior directed at a localizable signal for response-independent food, pecks on the signal key for the different-key group were recorded. Figure 3 presents the rate of pecking on the signal key during the CS for this group. Only D-2 and D-3 pecked the signal key to any significant degree. Signal-key rates for D-2 were higher for the first condition studied, the 48 sec condition, and these rates declined in succeeding conditions. Figure 2 shows that schedule-key responding during the CS increased as signal-key pecks declined for this bird. Bird D-3 was the only one which showed suppression of responding on the schedule key throughout the experiment, and the only bird which consistently maintained signal key pecking throughout the experiment. Thus, only D-3's data replicated Schwartz's (1976) finding that birds suppress responding on a schedule key while pecking a signal key. Pecks on the signal key obtained from D-3 and signal key pecks obtained from the birds in the FT group will, therefore, be examined to study the effects of other variables on signal-key pecking. For D-3 signal-key pecks declined as a function of the temporal location of the CS in the fixed interval for both determinations of the conditions.[1]

Pavlov (1927) found that responding conditioned by a long CS may be delayed until late in the CS, a phenomenon he called "inhibition of delay." This effect might also be expected in operant-classical interaction procedures. The change in behavior resulting from the CS presentation would then be expected to be more pronounced late in the CS. Alternatively, Rachlin (1973) has suggested that increased rates of responding resulting from the presentation of signals for increased reinforcement should occur at the transition from the absence to the presence of the signal. If this view is correct, changes in responding during the CS should be more pronounced early in the CS. In order to evaluate these alternative views of response patterning during a CS, response rates on the schedule key are plotted as a function of the time elapsed since the onset of the CS or control period. Data for both CS and control periods are plotted in Figures 4, 5, and 6. The data for the same-key group appear in Figure 4, for the different-key group in Figure 5, and for the FT group in Figure 6. As shown by the filled circles in the first panel for each subject, responding on the schedule key during a CS presented immediately after the last reinforcer increased throughout the CS, and differences between CS and control rates were more pronounced late in the CS. Only the data obtained from D-3 were an exception. An increasing rate throughout the CS was predicted by Pavlov and would seem to be an example of inhibition of delay. The increasing rates of schedule key pecking continue to be found when the CS is presented later in the interval for the FT and different-key groups. The data obtained with the original conditions for D-2 and with both sets of conditions for D-3 are an exception. In these cases responding on the schedule key decreased throughout the CS. It may be notable that these exceptions occurred only when the subjects were also pecking the signal key during the CS. For the birds in the same-key group, when the CS was presented later in the interval, responding did not increase throughout the CS as clearly as it did with the other groups, and in many instances responding did not increase at all during the CS. This result would not be predicted by either of the patterning views as just presented. An alternative account of these data will be proposed in Chapter 4.

Comparisons among Figures 4, 5, and 6 suggest that some group differences in patterning of responding during the CS are present. To further analyze this possibility suppression ratios were computed for the 2 sec bins since the CS onset for each condition. The ratios are shown in Figure 7. (Ratios are not plotted for the FT group, because control rates were at or near zero, essentially forcing the ratios to 1.0 for all conditions.) The ratios show how responding during successive periods of the CS compares to rates of responding occurring at the same time in control intervals. These ratios show clearly that subjects in the same-key group (open symbols) tended to increase responding above baseline levels to the same degree throughout the CS. In contrast, many of the subjects in the different-key group pecked at rates below control rates early in the CS and above control rates later in the CS. D-3 and D-2, the original conditions (the inverted triangles and solid squares) are exceptions. These birds pecked at rates below control rates at all times during the CS. The other different-key birds, however, differed from the same-key birds maximally in the first 2 sec of the CS.

Previous findings that birds will leave a schedule key and peck a signal key suggested that the suppression of responding below baseline response rates may be accompanied by signal key pecks. In the present study, however, only one subject, D-3, reliably pecked the schedule key throughout the experiment, and one subject, D-2, reliably pecked through a limited number of conditions. It may be, however, that some behavior directed toward the CS may be responsible for differences between the two groups in schedule key peck rates during the CS, and, as a consequence, occasional pecks to the signal key might occur at times when such signal-directed activity is maximal. In the present study signal-directed activity would be expected to be a maximal where group differences are greatest, soon after the onset of a CS presented late in the interval. To assess this possibility, pecks on the signal key are plotted as a function of the time since the onset of the CS for each condition for the different-key group, in Figure 8. As may be seen none of the subjects pecked the signal key at a maximum rate early in the interval. Thus, signal-key pecking either is not an indicator of signal-directed activity or signal-directed activity was not occurring. When signal-key pecks did occur, they were maximal late in the CS. This pattern of responding is similar to the signal-key pecking observed with the FT birds, and it could be most consistently observed with D-3 and with D-2 on the original conditions. It will be recalled that D-3 and D-2 also responded on the schedule key at lower rates late in the CS than early in the CS (Figure 5). These birds, therefore, show increasing signal-key pecks at times when schedule-key pecks are decreasing.

As differences in the same- and different-key groups are most pronounced early in the CS for most of the different-key birds, the effect of presenting the CS at a distance from the schedule key may be primarily on the response latency during the CS. Figure 9 presents response latencies during the CS as a function of the temporal placement of the CS. A similar measure timed from the onset of the control period is presented for comparison. In general, latencies were decreasing functions of the temporal location of the CS, although the relationship is least evident for the birds in the FT group. For birds in the same-key group CS response latencies were in all cases shorter than control latencies. In contrast, for the different-key group, CS latencies were shorter than the control latencies only when the CS began immediately after the fixed interval reinforcer. They became longer than control latencies in the 24 and 48 sec conditions. Thus, when the CS was presented in the middle or latter portions of the interval, a signal for free food located on the schedule key reduced response latencies, but a signal located at a distance from the schedule key increased response latencies. The effect is more evident in Figure 10. Ratios were computed using the response latencies obtained during the CS (L_{CS}) and during the control period (L_C) using the formula $L_{CS}/(L_{CS} + L_C)$. The latency ratio is analogous to the suppression ratios computed with the response-rate data. Values above 0.5 indicate longer response latencies during the CS, values at 0.5 indicate no change in latencies during the CS, and values below 0.5 indicate shorter latencies during the CS. The ratios for the birds receiving the CS on the schedule key were variable, but they remained consistently below 0.5, indicating that the CS reduced response latencies at all placements. When the CS appeared on the other key, the ratios increased as a function of the temporal location of the CS in the fixed interval. Thus, for the different-key group, latencies were reduced by the presence of the CS early in the fixed interval, and they were increased by the presence of the CS late in the interval.

The data suggest that lower response rates on the schedule key during the CS may be due primarily to the differing latencies. To further evaluate this possibility, the rates of responding during the CS and control periods were computed by subtracting the duration of the response latency. Figure 11 presents these running rates. During control periods running rates increased as a function of the temporal location of the control period. During CS periods, however, the functions relating running rates to the time of the CS onset differed between subjects. For this reason the effects of the time of the CS onset on CS response rates may be best explained in terms of the more orderly latency data. Between-group differences in running rate are still evident, however. For example, running rates for the same-key and FT groups were generally higher than rates for the different-key group. The effects of the spatial location of the CS on overall response rates on the schedule key during the CS must, therefore, be due both to changes in response latency during the CS and to rates of responding once responding has begun.

In summary, when the baseline was a simple fixed-interval schedule, the birds typically pecked the schedule key during the CS at increasingly higher rates as the CS was presented later in the interval. The changes in schedule key response rates accompanying the changes in temporal placement of the CS were found to be associated with systematic changes in the latency of schedule-key pecks, timed from the onset of the CS. Although the spatial relationship between the CS and the schedule key affected the rate of responding on the schedule key, only one bird consistently redirected pecks during the CS to the signal key. That bird pecked the schedule key at lower rates during the CS than during control periods. The other birds in the different-key group pecked the schedule key at a higher rate during the CS than during the control period. One other difference between the groups was found. The different-key birds consistently waited longer to begin pecking the schedule key after the CS onset than did the same-key birds. While this finding is consistent with a response competition theory of positive conditioned suppression, few pecks to the signal key were found for three out of the four different-key birds.

Tandem FI-DRL Conditions

Data in the preceding section showed the effects of the temporal and spatial location of the CS for conditions in which the baseline schedule was a simple fixed interval. In the present section the effects of an added pacing contingency on those variables are presented and compared with the effects found with the simple fixed interval schedule. Only the same- and different-key groups were studied with the pacing contingency, and only their data are reported in this section.

Other experimenters have found that responding during a CS increases above baseline levels more when a low-rate pacing contingency is employed than when no pacing contingency is employed. If these results are replicated in the present experiment, then suppression ratios found with the pacing contingency conditions should be higher than suppression ratios found with the simple fixed interval baseline. Figure 12 shows suppression ratios for the FI-DRL conditions (first panel) and for the simple fixed-interval recovery conditions (second panel). The data for the simple fixed-interval recovery conditions were previously plotted in Figure 1. The figure shows no consistent effect of pacing contingency on suppression ratios. For two birds in each group, S-1 and S-3 in the same-key group, and for D-1 and D-2 in the different-key group, the ratios obtained with the 24 and 48 sec conditions were higher with the pacing contingency than with the simple fixed interval schedule, the result expected on the basis of previous work. For S-2 in the same-key group and D-4 in the different-key group, however, the ratios obtained with the 24 and 48 sec conditions were lower with the pacing contingency than with the simple fixed-interval baseline, a result different from the usual finding. The ratios were unaffected for any subject when the CS was presented immediately after reinforcement. This would be expected because the baseline rates for these conditions were at or near zero for both baseline schedules forcing the suppression ratio to be at or near 1.0 if any responding occurred during the CS.

To further examine the effects of the pacing schedule on responding during the CS, the absolute rates of responding during the CS are plotted in Figure 13. The control period rates are also plotted for comparison. The data for both FI-DRL and fixed interval recovery conditions are included. The pacing contingency had similar effects on control-period responding for all birds. Response rates late in the fixed interval were lower when the pacing contingency was in effect than when it was not, as may be seen by comparing the open circles connected by both the solid and dashed lines. Response rates during the control periods still increased across the interval, however. Only the slope of the increase was affected.

Schedule key response rates during the CS were also lower in most cases when the pacing contingency was in effect than when it was not. This may be seen by comparing the solid circles connected by the solid and dashed lines. There was also a change in the effect of the temporal location of the CS when the pacing contingency was introduced. When the baseline schedule was a simple fixed interval, response rates during the CS increased as the CS was presented later in the fixed interval for most of the subjects in all of the groups. When the baseline schedule was a FI-DRL, however, response rates during the CS were either constant across all temporal locations of the CS or, as in many instances, decreased as the CS was presented later in the interval.

In order to determine the reliability of these effects, an analysis of variance was computed using rates of schedule-key pecking during the CS for the different spatial and temporal locations of the CS for each baseline schedule. Only data from the same- and different-key groups were included in the analysis because no pacing contingency was added to the FT group's schedule. The data used for the simple fixed-interval conditions were averages of the replications of each condition. The analysis is presented in Table 3. As may be seen, the spatial location of the key had significant effects on the response rate during the CS. The schedule of reinforcement and the temporal location of the CS, however, did not significantly affect the rate of responding on the schedule key during the CS. When an analysis of variance was performed on the simple fixed-interval conditions for all of the groups (cf. Table 2), the temporal location of the CS was found significantly to affect the rate of responding during the CS. Apparently, the effects of the pacing contingency on response rate at different temporal locations of the CS neutralized the effects observed with the simple fixed-interval schedule. It will be recalled from Figure 13 that response rate as a function of the temporal location of the CS increased when the baseline was a simple fixed-interval schedule and was either constant or lower when the baseline schedule was a FI-DRL. The relationship is also indicated by the significant interaction between the baseline schedule, the temporal location of the CS, and the spatial location of the CS.

One effect of the pacing contingency is the introduction of new topographies to meet the requirement for reinforcement. Because a second key was lighted in the chamber at all times during the experiment except during food presentations, it is possible that some of these new topographies would include pecks on this second key, hereafter called the "collateral key." Figure 14 plots collateral key pecking in order to investigate the possibility that the changes in the CS and control rates of responding on the schedule key were accompanied by changes in activity directed towards the collateral key. Collateral-key pecks are plotted for both the same- and different-key groups. These pecks may also be called signal-key pecks for the different-key group when the CS was presented. Several of the different-key group birds increased collateral-key pecking during the control period after the pacing contingency was added, and D-1 and D-2 also increased signal directed pecks during the CS above the rates of signal key pecks observed when the baseline was a simple fixed-interval schedule. Thus, the pacing contingency increased signal-key pecking for some of the different-key group birds, but this occurred only when the birds were also pecking the same key during the control periods. That finding may be relevant to the search for reasons why birds in this experiment did not leave the schedule key to peck a distant signal key, and it will be discussed more thoroughly in Chapter 4.

One bird in the same-key group, S-1, began pecking the collateral key after the pacing contingency was added during both the CS and the control periods. When the CS and control periods occurred late in the fixed interval more collateral-key pecks occurred than when the CS and control periods occurred early in the fixed interval. That is, collateral-key pecks covaried with schedule-key pecks, suggesting that the collateral key pecks were also under control of the schedule. When the CS was presented on the schedule key for this bird, however, responding on the signal key was reduced below the rates of responding on the signal key observed during control conditions. Thus, the presentation of the CS for this bird had the effect of reducing the rate of collateral-key pecks and increasing the rate of schedule-key pecks while the CS was lighted (Figure 13). These data are interesting because they show an instance in which schedule controlled behavior, pecking the collateral key, is decreasing while signal-directed behavior, pecking the schedule key, is increasing, resulting in similar findings to those of Schwartz (1976) and Rachlin and Green (1977).

When the baseline was a simple fixed interval schedule, the patterning of schedule-key pecks within the CS differed for the different groups. Because group differences in overall rate of responding during the CS were still evident when the pacing contingency was added, it is of interest to see if the group differences in patterning of responding during the CS are also still evident with the FI-DRL baseline. In order to assess the effects of the pacing contingency on this patterning of responding within the CS, the rate of responding on the schedule key is plotted as a function of the time since the onset of the CS for each of the different temporal locations of the CS. Both the data for the pacing contingency conditions and the simple fixed-interval recovery (dashed and solid lines) and the data from the CS and control intervals (solid and open circles) are plotted for comparison. Figure 15 presents the data for the same-key group, and Figure 16 presents the data for the different-key group. For both groups, response rates during the control period were not much affected by time in the CS, whether or not the pacing contingency was in effect. In contrast, during the CS with the pacing contingency in effect, (closed circle, dashes line), the birds from both groups, except D-3, responded at increasing rates throughout the CS for all temporal locations of the CS. When the simple fixed-interval schedule was in effect however, only the different-key group, except D-3, responded at increasing rates throughout the CS for all temporal locations of the CS. Increases in responding throughout the CS for the same-key group were either greatly reduced or completely eliminated when the CS was presented late in the interval. Thus, the effect of spatial location of the CS on overall rates of responding during the CS when the baseline was a FI-DRL schedule may not be attributed to group differences in response patterning during the CS.

Figure 14 shows that some different-key birds began pecking the signal key during the CS when the pacing contingency was in effect even though they had not previously pecked the signal key when the simple fixed-interval schedule was in effect. Thus, the patterning of signal-directed behavior throughout the CS may be observable with the FI-DRL conditions even though it was not observable with the simple fixed-interval conditions. Figure 17 presents pecks on the signal key for the different-key group as a function of the time since the onset of the CS for the FI-DRL conditions and for the recovery conditions with the simple fixed interval schedule. The figure shows that when signal key pecks occurred to any significant degree, the rate of signal key pecks increased as a function of the time since the onset of the CS. Thus, for most of the different-key group birds, except D-3, the rate of signal-key pecks and schedule-key pecks both varied directly with the time since the onset of the CS. For D-3 which pecked the signal key during the CS at higher rates than any other bird, signal-key pecks and schedule-key pecks varied inversely. Like other birds who pecked the signal key, D-3 pecked the signal key at increasing rates throughout the CS. Unlike the other different-key group birds, D-3 pecked the schedule key at decreasing rates throughout the CS

In the fixed interval conditions, increases in the rate of responding during the CS as a function of the temporal location of the CS were found to depend primarily on response latencies during the CS. In the FI-DRL conditions, overall rates of responding during the CS were lower than in the simple fixed interval condtions; furthermore, when the pacing contingency was in effect, schedule key responding during the CS did not increase as the CS was presented later in the fixed interval. Figure 18 plots latencies for the FI-DRL conditions to assess the contribution of response latencies during the CS to these changes. The recovery conditions with the simple fixed-interval baseline are also plotted for comparison. When response latencies were measured during control periods immediately after reinforcement, the pacing contingency had no effect on the speed with which the birds began to peck the schedule key. When control periods were measured later in the interval, however, the birds responded less quickly after the onset of the control period when the pacing contingency was in effect than when the baseline was a simple fixed interval. These increased latencies during control periods for the FI-DRL conditions probably reflect longer interresponse times generated by the pacing contingency. When the CS was presented late in the interval, the birds also responded less quickly after the onset of the CS with the pacing contingency than without. Thus, the reduction in schedule-key response rates during the CS produced by the addition of the pacing contingency was at least partially a result of lengthened response latencies timed from the onset of the CS.

Latency ratios, discussed earlier, were also computed for these data to assess the direction and magnitude of changes in baseline responding due to the presentation of the CS. Figure 19 presents these ratios as a function of the temporal location of the CS. The major effect of the pacing schedule on this measure was to move the values of the ratio closer to 0.5. This may be seen by comparing the dashed lines for each subject with the solid lines. In most cases the dashed line is displaced closer to the 0.5 mark than the corresponding solid line. Thus, the CS had less of an effect on the baseline response latency with the FI-DRL than with the simple fixed-interval schedule. For the different-key group (solid symbols) this change took the form of reducing the slope of the function relating the ratio to the temporal proximity of the CS to the fixed interval reinforcer. The CS latencies early in the interval continued to be short relative to control period latencies. In contrast, for the same-key group (open symbols) the slope of the function relating the latency ratios to the temporal location of the CS when the pacing contingency was in effect was reversed from that found when the simple fixed-interval schedule was in effect. In both the fixed interval and FI-DRL conditions the CS latencies were reduced relative to control conditions; but, when the baseline was a simple fixed interval, the CS reduced the latencies below control values less when it was presented early in the fixed interval than when it was presented late in the fixed interval. When the baseline was a FI-DRL the CS reduced latencies below control values more when it was presented early in the interval than when it was presented late in the interval.

When the fixed-interval schedule programmed reinforcement for baseline responding, the functions relating rate of responding during the CS to the temporal location of the CS were attributed largely to changes in the latencies, because running rates were not consistently related to the time of CS onset. When the FI-DRL schedule programmed reinforcement, however, the running rates declined, with some reversals, as a function of the temporal location of the CS. These data are shown in Figure 20. Thus, the flat or decreasing overall response rate function was a joint effect of steeply decreasing running rates and less sharply decreasing response latencies.

In summary, the pacing contingency decreased baseline schedule-key response rates; and, correspondingly, the rate of pecking the schedule key during the CS during these conditions was lower than when the baseline was a simple fixed interval. This was found to be due both to changes in the running rate during the CS and to longer response latencies during the CS. In addition, the rate of schedule-key pecking during the CS was either a declining or flat function of the time of the CS onset. This contrasted with the increasing functions relating response rate during the CS with the time of the CS onset for the fixed interval conditions.

Control Conditions

In all of the conditions just discussed a stimulus paired with food was presented at different times in the fixed interval, and the assumption was made that the pairing of the CS and US was an important determiner of the obtained performance. It is possible, however, that the stimulus alone or food unpreceded by a stimulus change may have been sufficient to produce these results. Consequently the effects of a stimulus alone, the CS_0, presented at different times in the fixed interval (Figure 21), and the effects of response independent food presented at different times in the fixed interval (Figure 22), were studied. Before the CS was presented during the fixed interval, it was presented randomly with respect to food presentations. For both figures the control period and CS rates for the recovery fixed interval conditions are plotted for comparison.

In both figures it may be seen that the stimulus alone and food alone were insufficient to produce the large differences between control intervals and intervals in which a stimulus was intruded; furthermore, there was very little responding either during the CS_0 or during the unsignaled period preceding the presentation of the intruded food when there was no baseline response requirement (the FT group). Thus, the pairing of the stimulus with food seems to be an essential determiner of the obtained results.

CHAPTER IV

DISCUSSION

In the Introduction a classification system for categorizing and predicting the effects of independent variables in positive conditioned suppression research was presented. The classification, based on Staddon's (1972) and Staddon and Simmelhag's (1971) conception of conditioning, proposed that there are two basic types of variables: motivational variables, affecting the amount of terminal behavior occurring in a situation; and directing variables, determining the form of the terminal behavior. The results of the present experiment will be compared with the predictions derived from this classification system.

The Effects of Motivational Variables

Staddon (1972) and other authors (Gibbon, Berryman & Thompson, 1974; Hearst & Jenkins, 1974; Stubbs, Hughes, & Cohen, 1978) have suggested that the rate of responding during a stimulus paired with food depends on such variables as the rate, delay, or amount of reinforcement during the stimulus relative to the rate, delay, or amount of reinforcement presented in the absence of the stimulus. According to this view, increased responding during the stimulus is predicted when more reinforcement is generally presented during the CS than in the absence of the CS. The relative rate of reinforcement is consequently higher during the CS, and, according to the view just stated, response rates during the CS should increase above baseline response rates.

In the present experiment the relative delay of the two sources of reinforcement, the US and the baseline reinforcer, was studied. Relative delay of reinforcement during the CS in the present experiment, however, may be calculated in at least two ways; and the predicted effects of this variable would depend on which calculation was chosen. According to one calculation the delay reinforcement signaled by the CS may be compared with the average delay of reinforcement signaled by the baseline conditions. This view will be called the molar interpretation of the relative delay hypothesis. According to the other calculation, the delay of reinforcement signaled by the CS is compared with the delay of the baseline reinforcer signaled at the time of the CS presentation. This view will be called the molecular interpretation of the relative delay hypothesis.

The calculations of relative delay of reinforcement mentioned above employed the term, average delay of reinforcement. In the present usage this term will refer to the average of all possible delays of reinforcement for the relevant time period, so that the delay of reinforcement at the midpoint of the time period under consideration would be the average delay.

According to the molar interpretation, the average delay of the US would always be 3 sec, and the average delay of the fixed interval reinforcer would always be 30 sec. Thus, the relative delay of food calculated as the ratio of these two delays would be 0.1 for all conditions during the CS, and responding during the CS would be expected to remain invariant regardless of the time of the onset of the CS in the fixed interval. Evidence for this invariance was found only when the pacing contingency was in effect. Even for these conditions, however, several of the subjects decreased their rate of responding as the CS was presented later in the interval, and D-2 increased his response rate as a function of the time of the CS onset. While different, these effects were so consistent that control by this invariant ratio seems unlikely. Also when the baseline schedule was a simple fixed-interval or fixed-time schedule, all but two subjects increased their rate of responding as the CS was presented later in the fixed interval. The exceptions were D-2 during the first set of CS onset times studied and I-3 for all conditions. These data are presented in Figures 2 and 13. Thus, this molar view of the effects of relative delay of reinforcement is not consistent with the present data.

According to the Molecular interpretation, the relative delay of reinforcement during the CS would increase as a function of the time of the CS onset in the fixed interval: the average delay of reinforcement during the CS was always 3 sec. but the average delay to the food at the end of the FI decreased as a function of the time of the CS onset. The average delay for these periods and their ratio are presented in Table 4.

So long as the delay of food during the CS is shorter or equal to the delay of food during the control period, the relative delay will vary between 0 and 1.0. Small relative delays correspond to conditions in which the discrepancy between the delay associated with the CS and the delay associated with the control period is large. Thus, under these conditions the CS would be expected to control a higher rate of responding than when there is a smaller discrepancy between the two delays. A small discrepancy would occur when the CS is presented at times late in the fixed interval. Thus CS controlled responding during the CS should decrease as the CS is presented later in the fixed interval showing less of an increase above baseline response rates. This prediction is similar to a proposal made by Osborne and Killeen (1977). They varied the duration of the CS, and as the CS increased in duration, the discrepancy between the rate of reinforcement during the CS and baseline conditions decreased. They found that with increasing CS durations, response rate during the CS approached the baseline rate.

In the present study, the response rates during the CS were more similar to the baseline rates when the CS was presented late in the interval than when the CS was presented early in the interval. This effect may be seen in Figures 1 and 12. Response rates during the CS and control periods are most similar as the suppression ratio approached 0.5. In these figures the ratios were closest to 0.5 when the CS was presented late in the interval, a time when there is less discrepancy between the delays associated with the CS and control periods. The function relating the absolute rate of responding during the CS to the time of the CS onset, however, was not consistent with the molecular relative delay hypothesis. When the baseline schedule was a simple fixed interval response rates during the CS increased as a function of the time of the CS onset rather than decreasing as the molecular view of relative delay would predict. Only when the baseline rate was reduced by the pacing contingency was there evidence for decreasing response rates during the CS as a function of the time of the CS onset.

In spite of the problems mentioned the relative delay notion need not be rejected. The predictions just evaluated were based on two simplifying assumptions which need not be made. The first assumption was that schedule key pecking represented the sum of all terminal activities, and the second assumption was that the discrepancy between the delays signaled by the CS and those signaled by time since food was the only determiner of the amount of terminal activity observed during the CS.

As noted previously, terminal activities may often consist of activities other than those explicitly reinforced by the experimenter. In the present experiment, in fact, two manipulations should have resulted in topographies of terminal activity other than schedule key pecking. These manipulations were the introduction of the pacing contingency and the presentation of the CS on a key at a distance from the schedule key. Schedule-key pecking, therefore, should positively correlate with terminal activity only when the simple fixed interval schedule was in effect for the same-key group subjects. Under these conditions schedule-key response rates increased with the time of the CS onset. Thus, it is reasonable to assume that the amount of terminal activity also increased with the time of CS onset for all birds regardless of CS location or the presence of a pacing contingency.

It is also reasonable to expect that the discrepancy between the delays signaled by the CS and time since food affected the amount of increase in terminal activity as a result of the CS presentation rather than the absolute amount of terminal activity during the CS. The CS is presented within the context of the fixed-interval schedule, and, as the CS is presented at successively later times in the interval, the delay of the baseline reinforcer is shortened. Correspondingly, the rate of schedule key pecking should increase with successively later times of CS onset. In fact, when a key color change not followed by food, the CS^o was presented at successively later times in the interval, pecking increased as a function of the temporal location of the intruded key light change. The relative delay of reinforcement during the CS then, may control only pecks in addition to those observed with the CS^o control conditions. Thus, many pecks may be added early in the interval as a result of a low relative delay signaled by the CS, but these pecks are added to a low baseline level of pecking. Similarly, fewer pecks may be added when the CS is presented late in the interval, but they are added to a high rate of pecking generated by the proximity of the baseline reinforcer. The result may be an increase in total pecks during the CS as a function of the temporal location of the CS.

Thus, the amount of terminal activity should increase as a function of the temporal location of the CS, but the increment in terminal activity during the CS should be a decreasing function of the time of the CS onset, as predicted by the molecular relative delay hypothesis. When all topographies of terminal activity would be expected to be schedule key pecks, the rate of pecking increased as a function of the time of the CS onset, and the increment in pecking during the CS above baseline rates, as shown by the suppression ratio, decreased as a function of the time of the CS onset. These results support the notion that the molecular relative delay hypothesis applies to increments in responding during the CS.

The previous analyses of the data were concerned with the average rates of responding during the CS and control periods. These analyses may also be extended to responding as a function of the time since the onset of the CS. In addition to looking at the effects of the average delay of food during the CS and control periods, the effects of the delay of food in different time bins during these periods may be studied.

To this point in the paper relative delay has referred to a comparison between the delays signaled by two different stimuli, the baseline stimuli and the CS. In the literature, however, a second type of relative delay or relative proximity to food has been discussed (Jenkins, 1970; Staddon, 1972). Here the reference is to the immediacy of food at a given time in the interval relative to the interfood interval. Because responding on fixed interval schedules has been found to be related to the relative rather than the absolute proximity to food (Jenkins, 1970), comparisons between the relative rather than absolute proximity to the US and baseline reinforcer will be considered.

Early in the fixed interval, the baseline proximity to food is low relative to the duration of the interval between scheduled food deliveries, and the baseline response tendency is low. As the time elapses in the interval the relative proximity to food increases, and the tendency to respond also increases. Similarly, at the onset of the CS the proximity to the US is low relative to the 6 sec CS duration, but the relative proximity to food during the CS increased at a much higher rate than the relative proximity to the next baseline reinforcer. When the CS is presented at different times in the fixed interval, the relative proximity to both the baseline reinforcer and the US may interact to determine the frequency of observed terminal activities. This relationship is depicted in Figure 23. For both baseline and CS conditions the relative proximity is computed by dividing the elapsed time since the onset of the CS or fixed interval by the duration of the CS or fixed interval, respectively. As can be seen in the figure, when the CS is presented early in the fixed interval both relative proximity functions are low at the onset of the CS, and only the CS relative proximity function is increased to a high value during the CS period. The combined functions would predict steeply increasing amounts of terminal activities during the CS period when the CS was presented at 0 sec since food. When the CS is presented at 24 sec since food, the CS relative proximity curve is low at the onset of the CS and steeply increasing, but the baseline relative proximity curve at the start of the CS is at an intermediate value increasing throughout the CS at a slower rate. Here the combined functions would predict a higher rate of responding at the CS onset than when the CS was introduced at 0 sec since food and an increasing rate with time in the CS. Also the maximum rate would be higher than the maximum rate obtained when the CS was presented immediately after the last fixed interval reinforcer. This result might not be visible if a ceiling response rate was reached. When the CS was presented at 48 sec since food, this view would predict that the rate of responding at the onset of the CS would be above the rate at the onset of the 24 sec condition unless a ceiling rate had been reached and the maximum rate should increase above the maximum obtained when the CS was presented at 24 sec since food. These predicted results may be compared with the rates during the CS plotted in Figure 4 for the fixed-interval conditions for the same-key group. Because in these conditions the topographies controlled by the baseline contingencies and the CS-US pairing should both be pecking the schedule key, these conditions should reflect the patterning of terminal activity. As may be seen in the figure, the rates during the CS for these conditions were consistent with the predictions made by the combined relative proximity functions.

In summary, data obtained with the same-key group and a simple fixed interval baseline schedule support the notion that the amount of terminal activity is affected by variables such as delay of reinforcement which were classified as motivational variables in the present classification scheme. For the subjects under these conditions schedule key pecking during the CS increased above baseline rates observed during the appropriate control periods at all temporal placements of the CS. That is, when a more immediate reinforcer was signaled, terminal activity increased. The amount of the increase was found to depend on the discrepancy between the delay signaled by the CS and that by the time since food. Increases in terminal activity produced by the CS were greater when a short delay to the US was compared with long delays to the fixed interval food than when a short delay to the US was compared with a short delay to the fixed interval food.

Patterning of terminal activity within the CS was also affected by a motivational variable, the relative proximity to food. According to Staddon (1972) and Jenkins (1970), when food is presented at fixed intervals, terminal activity becomes most probable at times when the food is proximal relative to the interfood interval. To apply this Relative Proximity Principle to the present data, it is necessary to be concerned with the relative proximity of the food presentations. Within each condition in the present study each time since the onset of the CS bore a consistent temporal relationship to both the US and the baseline reinforcer and relative proximity functions relating the time since the CS onset to the proximity to food could be plotted for both food presentations. When schedule-key pecking was the only expected terminal activity, it was found that terminal activity varied with time since CS onset in a pattern consistent with some type of interaction of these two relative proximity functions. Because no motivational variables were varied when the pacing contingency was introduced or when the CS was presented on a separate key, the amount and pattern of terminal activities for these conditions should be the same. Only the form should vary.

The Effects of Directing Variables

According to the classification scheme developed earlier, directing variables are variables which determine the form but not the amount of temporal distribution of terminal activity. This may be accomplished either by imposing a response contingency or by producing conditions that alter the topography of the terminal activity according to the Principles of Variation. In the present study, two directing variables were employed, the location of the CS relative to the manipulandum and the presence versus the absence of a reduced rate contingency, the pacing contingency. Both of these variables would be expected to affect the topography of terminal activity in specific ways. Moving the CS away from the schedule key should reduce the rate of pecking the schedule key below that observed when the CS is on the schedule key, because pigeons tend to peck signals paired with food. In addition, pecks on the signal key should be observed. Imposing the pacing contingency should reduce the baseline rate of pecking below that observed when no such contingency is in effect, and, to the extent that behavior reinforced by the baseline schedule continues to occur during the CS, schedule-key pecking during the CS should be reduced below that observed when there is no pacing contingency. These predictions are examined in the sections that follow.

The effects of the CS's spatial location. A number of theorists have suggested that operant-classical interactions may best be explained by postulating that CS's for unconditioned stimuli generate behavior that may either add to the responses maintained by the operant baseline schedule or interfere with the execution of these responses (Blanchard & Blanchard, 1969; Hearst & Jenkins, 1974; Kamin, 1965; Karpicke, Christoph, Peterson & Hearst, 1977; Schwartz, 1976). In the language of Staddon and Simmelhag (1971) these responses result from the Principles of Variation and the reduced selection allowed by the response-independent US.

When responses are added, response facilitation is observed during the CS and when interfering responses are generated response suppression is observed during the CS. Recent theories proposed by Staddon (1972), Hearst and Jenkins (1974), and Schwartz (1976) have specifically suggested that positive conditioned suppression procedures produce their effects by inducing the subject to approach a CS paired with food. If the CS is located near the manipulandum for the operant being trained, the CS will produce increased rates of responding. If it is located at a distance from the manipulandum, it will produce decreased rates as the subject leaves the manipulandum to approach the CS. When pigeons are presented a CS paired with food, the approach response is also generally accompanied by pecks directed at the CS (Hearst & Jenkins, 1974; Schwartz, 1976). In the context of positive conditioned suppression several investigators have demonstrated that pigeons will leave the operant manipulandum to approach and peck a lighted response key that signals food (LoLordo et al., 1974; Green & Rachlin, 1977; Schwartz, 1976). In addition, they found that a CS paired with food located on the schedule key will induce increased rates of pecking on the schedule key.

The present experiment found that pigeons did increase rates of pecking during a CS located on the schedule key, but only one out of four subjects consistently approached and pecked a CS located on a separate key. For this bird responding on the schedule key was reduced during the CS. For the other three birds the rate of pecking on the schedule key during the CS increased. While these data are not inconsistent with a response competition theory of operant-classical interaction effects, they do suggest that birds will not always leave the schedule key to peck a distant signal for food.

There is, nevertheless, evidence in the present study that suggests that these pigeons were reacting to the CS in a manner that interfered with pecking on the schedule key. Even though most birds did not approach and peck the CS when it was presented on a separate key, observations indicated that they oriented toward the CS when it first came on. In fact, the response latencies during the CS were generally longer when the CS was presented on a separate key than when it was presented on the schedule key. This finding suggests that at least early in the CS, behavior directed toward the CS interfered with the execution of the operant. Once the pigeon initiated responding during the CS, however, the rate of responding was higher than the comparable rate of responding during the control period.

The accelerated responding during the CS would indicate that more terminal behavior occurs in the presence than in the absence of the CS. The topography of this behavior may be complexly determined such that the location of the CS is only one of several inputs. The present study suggests that locating the CS on the schedule key for pigeons will result in a topography that has the effect of closing the key switch and adding to the number of recorded responses. Locating the CS on a separate key, however, is not a powerful enough variable to inevitably redirect the pecks to a separate key.

Other inputs which may be important are variables which affect the initial tendency to engage in pecking on the signal key and the strength of the competing operant relative to the strength of other responses. In the present study the subject who most consistently pecked the signal key also tended to peck the same key when the CS was not present, the collateral key. This occurred even in the baseline conditions before the CS and US had been superimposed on the operant baseline and the reasons for this performance are not clear. The presentation of the CS, however, increased the rate at which the collateral key was pecked. The other birds in the different-key group tended not to peck the collateral key in the absence of the CS. When the pacing contingency was added, however, several of the different-key group birds began to peck the collateral key reliably during baseline responding. When this occurred, for two of the birds there was also an increase in signal directed pecking above baseline rates.

Another factor that may have influenced the topographies is the strength of the baseline response at the time of the CS presentation. This proposal is similar to one made by Nevin (1974). He suggested that the relative strength of responses may best be defined by observing the amount of change in responding produced when a disrupting condition is introduced. Examples of such disrupting conditions might be the introduction of extinction or signals for shock or food. Variables such as magnitude of reinforcement for a discriminated operant were found to bear orderly relations to the amount of change generated by the disruptions.

In the present experiment disruption produced by presenting a CS at a distance from the schedule key should be more pronounced when the strength of the baseline operant is low. The performance of D-3, who consistently pecked the signal located on a separate key, provided evidence for this. D-3 pecked the signal key most frequently at times early in the fixed interval when the delay to reinforcement was high and the strength of the baseline response was, therefore, low. As the CS was presented at times when the delay to reinforcement was shorter for pecking the schedule key, signal-key pecks declined. This effect was replicated using both fixed interval and FI-DRL baseline schedules.

The notion that responses with high strength are less easily disrupted by the CS would also predict the obtained group differences with respect to rate of responding directed toward the signal. For the different-key group schedule-key pecking has a high response strength, and the CS would tend to elicit behavior incompatible with the baseline response. Thus, the topographies observed during the CS should be a combination of schedule-key pecks and signal-directed behavior. Because the schedule-key pecks have a high response strength, a large proportion of the observed topographies should consist of schedule-key pecks. For the FT group no specific response was required during the fixed interval although the birds were presumably engaged in terminal behavior late in the interval. The topography of the terminal activity, however, could vary without affecting the rate of reinforcement. A large body of data suggests that the strength of a response is related to the relative rate of reinforcement for the response. Thus, for the FT group no one response would necessarily acquire a high response strength. In fact, response strength for any one response would be inversely related to the variability of the terminal activity emitted during the interval. The baseline behavior, therefore, would be easily disrupted, and the CS would induce more signal-key pecks, a topography incompatible with the baseline responses usually observed during control periods. For the same-key group baseline responding has a high response strength, and the CS would also induce the subject to peck the schedule key. Thus, the observed topography during the CS will be primarily schedule key pecks. Inasmuch as the frequencies and delays of reinforcement were the same for all groups, it is reasonable to assume that the amount of terminal activity was the same for all of the groups. Therefore, the absolute rate of signal directed responses for each group should reflect changes in the proportion of total responses directed to the signal key. Figure 24 presents the mean rate of signal-key pecks for each group when the baseline schedule was a FI. The observed group differences are consistent with the predicted proportions of total response that should be directed at the signal key. An analysis of variance found that these differences were statistically significant ($\alpha = .05$). Table 5 presents the results of this analysis.

In summary, the location of the CS had some of the predicted effects on responding during the CS. Schedule key response rates during the CS were less when the CS was on a separate key than when it was on the schedule key. The rates did not, however, decrease below the control period rates when the CS was on a separate key nor did a majority of the subjects redirect their pecking to the signal key during the CS. This suggests that the proposed Principle of Variation stating that pigeons approach and peck signals for food is modulated by other variables. Modulating variables which are suggested by the present data were the delay and frequency of reinforcement for the baseline response and variables determining the initial tendency of the subject to engage in the response generated by the CS-US pair.

The effects of the pacing contingency. The pacing contingency employed required that 4 sec elapse between the schedule key pecks resulting in reinforcement, and the usual effect of such a contingency on fixed-interval schedule performance is a decrease in response rate throughout the interval (Farmer & Schoenfeld, 1964). Because the baseline schedule for the FI-DRL conditions restricts the minimum time between key pecks, it seems likely that a new topography would emerge to meet the spacing requirement, and as terminal behavior becomes more probable late in the interval, the frequency of the new alternative topography would increase. Evidence of this type of phenomenon may be seen in Figure 13. When the pacing contingency was added, several of the birds began pecking the collateral key during the baseline conditions, and the birds increased their rate of pecking this key during the control period as a function of time in the interval. As mentioned above, when the CS was presented at successively later times in the fixed interval, the terminal activity during the CS should increase. For these conditions the terminal activity would consist of activities determined by the baseline contingency, namely schedule key pecks and the alternative activity, and any topography determined by the CS location. If the likelihood of observing a given topography during the CS increases with the strength of that topography in the absence of the CS , and on fixed-interval schedules the baseline strength of reinforced responses increases with time in the interval, then the frequency of alternative topographies mixed with schedule-key pecks during the CS should be maximal late in the interval. This would mean that a smaller portion of the total terminal activity during the CS would be pecks induced by the CS location and a larger portion would be the unmeasured alternative topography. Thus, the schedule-key pecking rates during the CS may either be flat or decreasing functions of the time of the CS onset, due to the increasing amounts of alternative terminal activity topographies late in the fixed interval.

There are two lines of evidence for this view in the present data. The first may be seen in the behavior of S-1 in Figure 14. S-1 began pecking the collateral key at a high rate during baseline conditions when the pacing contingency was added. Thus, the rate of these pecks may serve as an indicator of changes in the frequency of alternative topographies induced by the pacing contingency. This interpretation of these pecks receives support from the fact that collateral-key pecks decreased for this bird when the simple fixed-interval schedule was reinstated. When the CS was presented, the collateral-key pecks decreased below the baseline rates and the rate of schedule key pecking increased. It should be noted that for this bird the CS was located on the schedule key and increased schedule-key pecks may be at least partly due to the induction of signal-key pecks. The rate of collateral-key pecks during the CS, however, increased as a function of the time of the CS onset as predicted by the above analysis.

The other evidence for this view may be seen in the running rates for the pacing contingency conditions. If the alternative topography becomes an increasing proportion of terminal activity late in the interval during the CS, then responding during the CS, once it commences, should be increasingly interrupted by the alternative topograpy. This would result in reduced running rates as a function of the time of the

CS onset. Figure 20 shows decreasing running rates as a function of the time of the CS onset for these conditions, as the present analysis would predict.

The Patterning of Terminal Activity Topographies

In earlier sections of the paper variables such as the relative proximity of reinforcement or the relative frequency of reinforcement in the presence of a stimulus were said to determine the amount of terminal activity generated in the presence of that stimulus. Staddon (1972) has also suggested that the same variables may affect the likelihood of observing one form of terminal behavior over another. For example, if the relative proximity of reinforcement is higher following a key peck than that following wing flapping, then key pecking will be selected to occur with a higher frequency than wing flapping.

In the present experiment, when conditions would favor the occurrence of two or more terminal activity topographies, the relative proximity of reinforcement may be studied as a possible determiner of the patterning of these various topographies. As mentioned earlier the relative proximity functions are relevant, one relating time in the CS to the relative proximity of the US and one relating time in the CS to the relative proximity of the baseline reinforcer. When the relative proximity of the US is higher, then activities generated by the nature of the CS should predominate. When the relative proximity of the baseline reinforcer is higher, then the activities required by the baseline schedule should predominate.

The data collected with the same-key group when the pacing contingency was in effect and the data collected for the FT and different-key groups for all conditions would be relevant to these predictions. In all of these cases the behavior generated by the baseline conditions should differ from behavior generated by the presentation of the CS.

This formulation would predict that, when topographies alternative to the required response are likely to be generated by the baseline schedule, then these activities should predominate when the baseline relative proximity function is higher than the relative proximity to the US during the CS, a condition occurring early in the CS. When the pacing contingency was added, alternative topographies became especially likely reducing the rate of the schedule-key pecks. During the CS this decrease in response rate should be most pronounced at times when the baseline relative proximity function is higher. Figure 15 illustrates this phenomenon. While the pacing contingency reduced pecking during the CS below rates obtained with the simple fixed interval schedule, the rate of responding during the CS was most reduced for the first 2 sec of the CS. This is particularly evident when the CS was presented at 24 and 48 sec since food.

When the CS generates behavior different from that occurring during baseline conditions, the behavior generated by the CS should increase as a function of time since the onset of the CS, matching the relative proximity function for time to the US. When there was no baseline response requirement, as with the FT group, then the function relating pecks on the signal key to time in the CS should be consistent with the function relating time in the CS to the relative proximity to the US. As shown in Figure 6, the rate of signal-key pecks for these birds increased as a function of time since onset, a finding consistent with these predictions.

When baseline responding was required, but the signal was presented on the other key, signal-key pecks should also increase with time in the CS. As shown in Figure 7 and 17, signal-key pecks for the different-key group did in most cases increase as a function of time in the CS, provided that signal-key pecks occurred. The most striking difference, however, between the same-key and different-key groups was the difference in response latencies during the CS. The different-key group subjects paused longer after the onset of the CS than the subjects in the same-key group. If the increase in latencies are presumed to result from the occurrence of food related activities incompatible with the reinforced response, then the relative proximity formulation just discussed would predict that these activities should be more likely later in the CS and there should be no difference in the latencies between these two groups.

One plausible explanation for the longer latencies occurring with the different-key group is that the color change on the signal key elicited an observing response. At the onset of the CS the birds may have briefly turned their heads to face the signal key and then returned to peck the schedule key. For the different-key group the observing response would require postural adjustments which would delay the birds' first peck on the schedule key, while for the same-key group an observing response would only require the birds to look at the schedule key so that the result, if any, would be to shorten the time to the first schedule key peck during the CS.

Because food is presented at the same rate in this experiment regardless of whether the birds observe the CS, it is not clear why these observing responses should occur. That is, observation of the CS cannot have an effect on food deliveries, yet the bird's behavior changed when there was an opportunity to observe a signal for increased food. One explanation may be that in the absence of the signal a less valid predictor of the free food, time since the fixed interval reinforcer, comes to control an increase in terminal activity even though these temporal stimuli are paired with the US on only one in four intervals. Evidence for this view is presented in Figure 22. When the CS signaled food, pecking increased during the CS and control period rates were low. When free food was presented unsignaled in one of four intervals, pecking increased during both the period preceding food by 6 sec and during control periods. If reducing the amount of terminal activity per reinforcer is rewarding, then observing responses would allow increased terminal activities to occur only when food is proximal.

Rather than observing the key on which the CS is presented, the birds may have been moving toward the CS key after the onset of the CS. This notion that responses to signals occur at the onset of the signal has been proposed by Rachlin (1973) and it may be termed a transitional view of response patterning in contrast to the relative proximity view described earlier. Rachlin proposed that birds approach a stimulus at its onset when it signals a bettering of conditions such as an increase in the relative proximity of reinforcement, and that they withdraw from a stimulus at its onset when it signals a worsening of conditions. Green and Rachlin (1977) have presented data which support this proposal. In their experiment a green key light alternated with a red key light and a variable interval 2 min schedule of reinforcement was in effect for pecking the lighted key. Additional response independent reinforcement was available on a variable time 15 sec schedule during the red component of the multiple schedule. They found that increases in response rate during the red component were concentrated early in the component, and decreases in response rate during the green component were also concentrated early in the component.

The data of the present experiment are consistent with two views of response patterning during a CS, a relative proximity view and a transitional view. Signal-key pecks, when they occurred, increased with the relative proximity to the US. Some response alternative to schedule key pecks, however, was also occurring for the different-key group at the onset of the CS. This finding would be consistent with the transitional view of response patterning during a CS.

The latency data, therefore, may be explained by either postulating observing responses or postulating Rachlin's (1973) transitional view of response patterning. If the observing response explanation is correct, then the latencies result from a contingency between looking and reducing the amount of terminal behavior per reinforcer, and the increases in signal key responding during the CS result from changes in the relative proximity of food.

If the transitional view is chosen, however, the data would be consistent with two seemingly alternative principles of response patterning, a relative proximity principle and a transitional principle. Accepting two alternative principles would seem to be unwieldy unless they may both be reduced to a single underlying principle. Both principles propose that behavior is generated by signaled changes in the likelihood of reinforcement. According to the relative proximity principle, the changes occur in small steps gradually and continuously with the passage of time. According to the transitional principle, the change occurs in a single discrete step as with the onset of a light. If the strength of the response generated by the stimulus change depends on the amount of change in reinforcement proximity, then it may be seen that a single discrete change in stimulus conditions may signal a bigger change in reinforcement proximity than continuous changes. Thus, stronger responses may be controlled by the onset of a discrete stimulus than by gradual changes associated with the passage of time. The strong response to the discrete change, however, may soon habituate because no further large changes are being signaled. Meanwhile the weaker response to gradual stimulus change would be maintained and strengthened because the delay of reinforcement is also being continuously shortened.

This view of the relative proximity and transitional principles further clarifies a puzzling result. The patterning of topographies of terminal activity during the CS was predicted by the relative values of two relative proximity functions. When the proximity of the baseline reinforcer relative to the fixed-interval value was higher than the proximity of the US relative to the CS duration, behavior appropriate to the baseline schedule took precedence over behavior appropriate to the CS. The only exception was the behavior occurring during the response latencies during the CS when the CS was located on a separate signal key. It would seem strange, however, that behavior appropriate to the baseline schedule should ever take precedence over behavior appropriate to the CS because the CS always signals a greater proximity to the US than to the fixed interval reinforcer. The transitional view described above can explain this finding with the exception of the response hypothesized to occur during the response latencies. The changes in proximity to reinforcement occurred gradually and therefore, responses associated with those changes should be weak and baseline responding may take precedence. At the onset of the CS the change in signaled reinforcement is great so that responses associated with this change are strong enough to take precedence over baseline responding, but because subsequent changes in reinforcement proximity are small, the response to the CS habituates and further patterning of terminal activity may result from interactions between the two relative proximity functions described above.

Conclusions

There have traditionally been two basic types of explanation for operant-classical interaction effects which apply to the positive conditioned suppression procedure. One of these explanations assumes that responses evoked by the classical conditioning procedure either enhance or interfere with the execution of the operantly conditioned response.

These classically conditioned responses have in some cases been assumed to be overt responses or in other cases covert responses limited to activity in the central nervous system. The other explanations assume that the classical procedure enhances motivation for the operant or the incentive stimuli to which the operant is conditioned.

Staddon's (1972) view of positive conditioned suppression encompasses elements from both views in a unified explanation. This is accomplished by focusing on the likelihood of observing terminal behavior rather than on restricting interest to the reinforced response, and by assuming that the topography of terminal activity may vary. Within this view variables which increase the amount of terminal activity would be the same variables which would confirm the motivation or incentive views of positive conditioned suppression. In addition, variables which affect the topography of terminal activity would generate effects consistent with the response competition view of positive conditioned suppression.

The data of the present experiment support the notion that variables may be identified which have these two types of effects. Varying the relative delay or relative proximity of reinforcement during the CS resulted in variations in schedule key pecking when schedule key pecking could be expected to be the only terminal activity, and varying response rate contingencies and location of the CS were found to affect the topography of terminal behavior in predictable ways.

The ability to categorize behavior as either interim or terminal activity is basic to the classification scheme evaluated. When operant-classical interaction studies involve the same stimulus as reinforcer and US, this presents few problems. Terminal activities are activities appropriate to the US and reinforcer. Frequently, however, different stimuli are used for the US and reinforcer in operant-classical interaction studies. Food pellets, for example, may serve as the US and sugar water may serve as the reinforcer. In circumstances such as these, different activities may be generated by stimuli associated with the US and reinforcer, and it may not be clear whether one of these activities should now be considered interim behavior or if both should be considered terminal behavior. The problem comes into sharper focus when the US is an electric shock and the reinforcer is a food pellet. It is hard to imagine that activities appropriate to food and to shock could both be the same class of terminal activities. If the term interim activity is reserved for behavior appropriate to uncontrolled reinforcers or US's, and the term terminal activity is applied to behavior appropriate to reinforcers and US's delivered at specific times by the experimenter, then the same rules found to apply in the simple case when the US and reinforcer are the same should also apply when the US and reinforcer differ. The distribution of terminal activities between behavior appropriate to the different stimuli should depend on the relative rate or proximity of the reinforcer or US.

CHAPTER V

SUMMARY

Previous experiments have shown that the classical conditioning procedure has effect on operant behavior. The effects may be modified by varying the rate of responding maintained by the baseline schedule and by varying the location of the CS with respect to the operant manipulandum.

A key color change associated with response independent food was presented to pigeons at different temporal locations within a fixed interval between food presentations and at different spatial locations within the chamber. For two groups of subjects the food presented at the end of the fixed interval depended on a key peck on a schedule key, and for one group all food presentations were response independent. For the response dependent reinforcement groups both a simple fixed interval 60 sec schedule and a fixed-interval schedule requiring low rates determined the baseline response rates for comparison with the response rates during the key color change. The spatial location of the color change differed for the two response independent reinforcement groups. For one group the key color change occurred on the schedule key and for the other group the key color change occurred on a separate signal key.

Response rates on the schedule key increased above baseline rates during the key color change for all but one of the response dependent reinforcement subjects. Larger increases in response rate were observed when the key color change occurred early in the interval between food presentations than when it occurred late. The effects of the baseline schedule were more clearly seen in the rates of responding during the key color change. These rates increased as a function of the time of the onset of the key color change when the schedule was a simple fixed interval, but the rates were constant or decreasing functions of the time of the stimulus onset when the schedule required a low rate.

In addition, larger increases in rate were observed when the key color change occurred on the schedule key. When all food presentations were response independent, pecking rates on the key on which the color changed were found to increase as a function of the temporal location of the key color change for two of the three birds in this group. These effects were found to be consistent with the view that variables such as temporal location of the CS affect the amount of food related or terminal activities observed during the CS and that variables such as rate requirements or location of the CS affect the form or topography of terminal activity.

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FOOTNOTES

[1] There were differences between subjects in the different-key group. D-3 pecked the schedule key less during the CS than during the control period, and this decline was accompanied by pecks on the signal key. The other subjects comprising this group pecked the schedule key more during the CS than during control periods. This difference raises questions about which effect of CS location should be generalized. Other studies (LoLordo et al., 1974; Schwartz, 1976; Green & Rachlin, 1977) found less schedule-key pecking during CS's located at a distance from the schedule key accompanied by increased pecks at the schedule key.

Any reply to such questions should remind the reader that such discrepant results indicate some ignorance of all of the variables contributing to the effects of CS location. Further research is needed to clarify these variables. Nevertheless, there were some notable consistencies among the data found from the birds in the different-key group: response rates during the CS were consistently lower for these birds, relative to the rates with either the FT or same-key conditions; furthermore, the schedule-key response latencies were longer for all birds in the different-key group, relative to the birds in the same-key group. Thus, the effects of CS location seem to be more robust than the inducement of measurable signal-key pecks.

APPENDIX A

TABLES

TABLE 1

The Number of Sessions for Each Experimental Condition

Subject	Condition	Sessions
Same-Key Group		
S-1	Classical conditioning:	
	Delay procedure	3
	FI baseline training	35
	FI and CS combined:	
	CS at 48 sec	23
	CS at 24 sec	20
	CS at 0 sec	20
	CS at 24 sec	15
	CS at 48 sec	11
	CS at 0 sec	10
	FI-DRL baseline training	23
	FI-DRL and CS combined:	
	CS at 0 sec	11
	CS at 24 sec	10
	CS at 48 sec	10
	FI baseline training	18
	Classical conditioning:	
	Truly random control procedure	2
	FI and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FI and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	12
	Free food at 54 sec	10

Subject	Condition	Sessions
S-2	Classical conditioning:	
	Delay procedure	2
	FI baseline training	42
	FI and CS combined:	
	CS at 48 sec	21
	CS at 24 sec	12
	CS at 0 sec	26
	CS at 24 sec	20
	CS at 48 sec	10
	CS at 0 sec	11
	FI-DRL baseline training	25
	FI-DRL and CS combined:	
	CS at 0 sec	10
	CS at 24 sec	10
	CS at 48 sec	10
	FI baseline training	20
	Classical conditioning:	
	Truly random control procedure	2
	FI and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FI and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	13
	Free food at 54 sec	10
S-3	Classical conditioning:	
	Delay procedure	8
	FI baseline training	41

Subject	Condition	Sessions
S-3 (continued)	FI and CS combined:	
	CS at 48 sec	24
	CS at 24 sec	16
	CS at 0 sec	30
	CS at 24 sec	12
	CS at 48 sec	11
	CS at 0 sec	10
	FI-DRL baseline training	23
	FI-DRL and CS combined:	
	CS at 0 sec	10
	CS at 24 sec	10
	CS at 48 sec	9
Different-Key Group		
D-1	Classical conditioning:	
	Delay procedure	10
	FI baseline training	39
	FI and CS combined:	
	CS at 48 sec	25
	CS at 24 sec	12
	CS at 0 sec	17
	CS at 24 sec	15
	CS at 48 sec	10
	CS at 0 sec	11
	FI-DRL baseline training	24
	FI-DRL and CS combined:	
	CS at 0 sec	10
	CS at 24 sec	10
	CS at 48 sec	10
	FI baseline training	15
	Classical conditioning:	
	Truly random control procedure	2

Subject	Condition	Sessions
D-1 (continued)	FI and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FI and free-food combined:	
	Free food at 6 sec	11
	Free food at 30 sec	13
	Free food at 54 sec	10
D-2	Classical conditioning:	
	Delay procedure	2
	FI baseline training	42
	FI and CS combined:	
	CS at 48 sec	22
	CS at 24 sec	19
	CS at 0 sec	42
	CS at 24 sec	10
	CS at 48 sec	10
	CS at 0 sec	11
	FI-DRL baseline training	21
	FI-DRL and CS combined	
	CS at 0 sec	10
	CS at 24 sec	10
	CS at 48 sec	10
	FI baseline training	18
	Classical conditioning:	
	Truly random control procedure	2
	FI and CS^{o} combined:	
	CS^{o} at 0 sec	9
	CS^{o} at 24 sec	11
	CS^{o} at 48 sec	14

Subject	Condition	Sessions
D-2 (continued)	FI and free-food combined:	
	Free food at 6 sec	11
	Free food at 30 sec	13
	Free food at 54 sec	10
D-3	Classical conditioning:	
	Delay procedure	2
	FI baseline training	45
	FI and CS combined:	
	CS at 48 sec	20
	CS at 24 sec	15
	CS at 0 sec	16
	CS at 24 sec	18
	CS at 48 sec	11
	CS at 0 sec	10
	FI-DRL baseline training	23
	FI-DRL and CS combined:	
	CS at 0 sec	13
	CS at 24 sec	10
	CS at 48 sec	10
	Classical conditioning:	
	Truly random control procedure	2
	FI baseline training	16
	FI and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	11
	CS^{o} at 48 sec	15
	FI and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	12
	Free food at 54 sec	11

Subject	Condition	Sessions
D-4	Classical conditioning:	
	Delay procedure	2
	FI baseline training	42
	FI and CS combined:	
	CS at 48 sec	34
	CS at 24 sec	21
	CS at 0 sec	19
	CS at 24 sec	10
	CS at 48 sec	14
	CS at 0 sec	10
	FI-DRL baseline training	20
	FI-DRL and CS combined:	
	CS at 0 sec	11
	CS at 24 sec	10
	CS at 48 sec	10
	FI baseline training	14
	Classical conditioning:	
	Truly random control procedure	2
	FI and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FI and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	11
	Free food at 54 sec	10
FT Group		
I-1	Classical conditioning:	
	Delay procedure	4
	FT baseline training	41

Subject	Condition	Sessions
I-1 (continued	FT and CS combined:	
	CS at 48 sec	21
	CS at 24 sec	15
	CS at 0 sec	18
	CS at 24 sec	15
	CS at 48 sec	13
	CS at 0 sec	11
	Classical conditioning:	
	Truly random control procedure	2
	FT and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FT and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	10
	Free food at 54 sec	10
I-2	Classical conditioning:	
	Delay procedure	2
	FT baseline training	41
	FT and CS combined:	
	CS at 48 sec	21
	CS at 24 sec	15
	CS at 0 sec	18
	CS at 24 sec	14
	CS at 48 sec	10
	CS at 0 sec	11
	Classical conditioning:	
	Truly random control procedure	2
	FT and CS^{o} combined:	
	CS^{o} at 0 sec	10
	CS^{o} at 24 sec	10
	CS^{o} at 48 sec	15
	FT and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	12
	Free food at 54 sec	10

Subject	Condition	Sessions
I-3	Classical conditioning:	
	Delay procedure	10
	FT baseline training	41
	FT and CS combined:	
	CS at 48 sec	21
	CS at 24 sec	14
	CS at 0 sec	16
	CS at 24 sec	15
	CS at 48 sec	10
	CS at 0 sec	11
	Classical conditioning:	
	Truly random control procedure	2
	FT and CS^o combined:	
	CS^o at 0 sec	10
	CS^o at 24 sec	10
	CS^o at 48 sec	15
	FT and free-food combined:	
	Free food at 6 sec	10
	Free food at 30 sec	10
	Free food at 54 sec	10

TABLE 2

Analysis of Variance of Schedule Key Pecks During The CS for the FI Baseline Conditions for all Groups

Source of Variance	SS	df	MS	F
<u>Between Subjects</u>				
Spatial location of CS	78543.03	2	39271.51	20.56**
Subjects within groups	13371.89	7	1910.27	
<u>Within Subjects</u>				
Temporal location of CS	5530.90	2	2765.44	7.77**
Temporal X Spatial location of CS	3444.22	4	861.05	2.41
Temporal location of CS X Subjects within groups	4984.00	14	356	

**Significant (α = 0.01)

TABLE 3

Analysis of Variance of Schedule Key Pecks for FI and FI-DRL Conditions with Same- and Different-Key Groups

Source of Variation	SS	df	MS	F
<u>Between Subjects</u>				
Spatial location of the CS	97393.50	1	97393.50	9.20*
Subjects within Groups	52934.16	5	10586.83	
<u>Within Subjects</u>				
Schedule of Reinforcement	17408.70	1	17408.70	4.77
Schedule X Spatial location of the CS	7834.95	1	7834.95	2.15
Schedule X Subjects within Groups	18255	5	3651	
Temporal location of the CS	3422.40	2	1711.20	3.14
Temporal X Spatial location of the CS	952.2	2	476.1	
Temporal location of the CS X Subjects within Groups	5452	10	545.2	
Schedule X Temporal location of the CS	4947.30	2	2473.65	
Spatial X Temporal location of the CS X Schedule	457953.00	2	228976.5	4.34*

Source of Variation	SS	df	MS	F
Schedule X Spatial location of the CS X Subjects within Groups	527519.00	10	52751.9	

*Significant (α = 0.05)

TABLE 4

Delays and Ratios of Delays of The Most Proximal Reinforcer

Time of CS Onset	Average Delay During CS	Average Delay During Control Period	Ratio of Delays
0	3	57	.05
24	3	33	.09
48	3	9	.33

TABLE 5

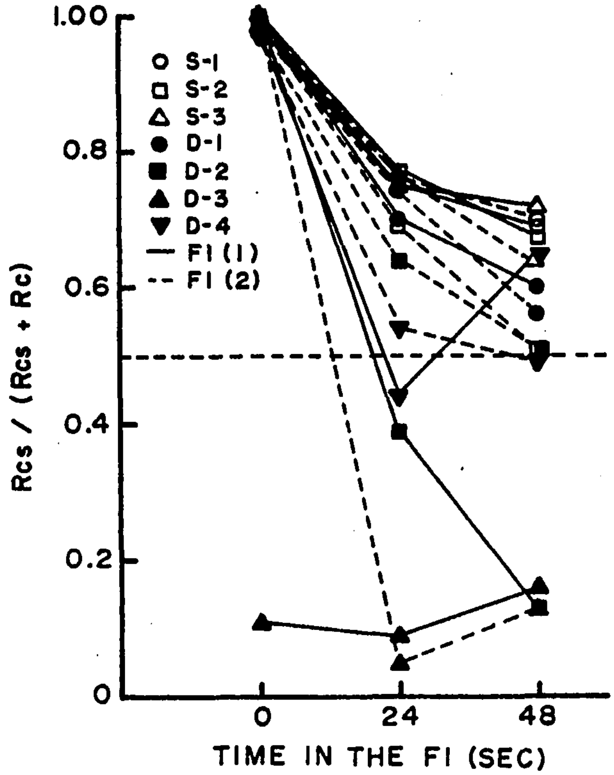
Analysis of Variance of Signal Key Pecks For FI and FT Conditions

Source of Variation	SS	df	MS	F
Spatial location of the CS	31394.71	2	15697.36	7.13
Within groups	15405.27	7	2200.75	

APPENDIX B

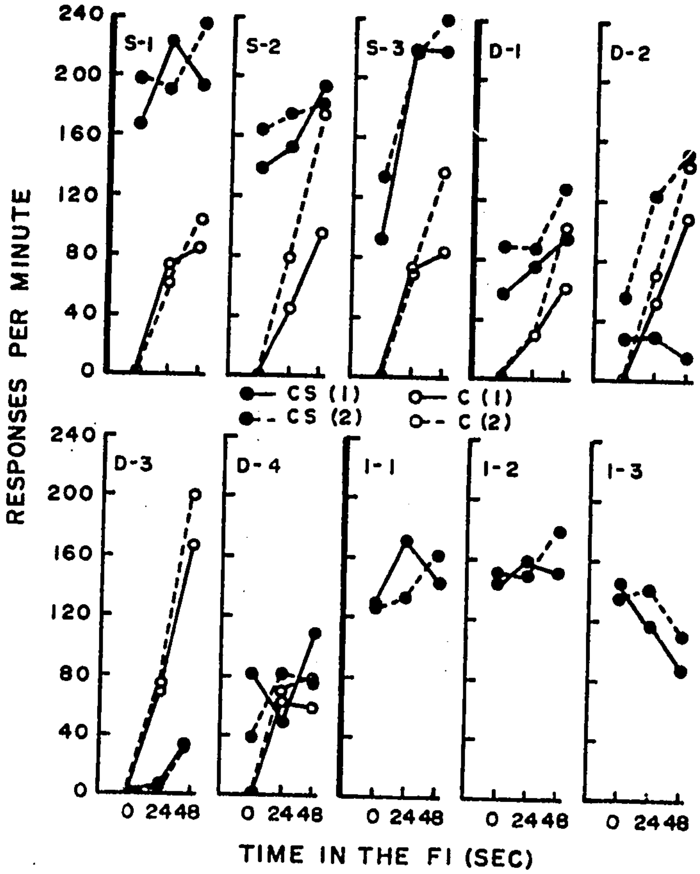
FIGURES

FIGURE 1



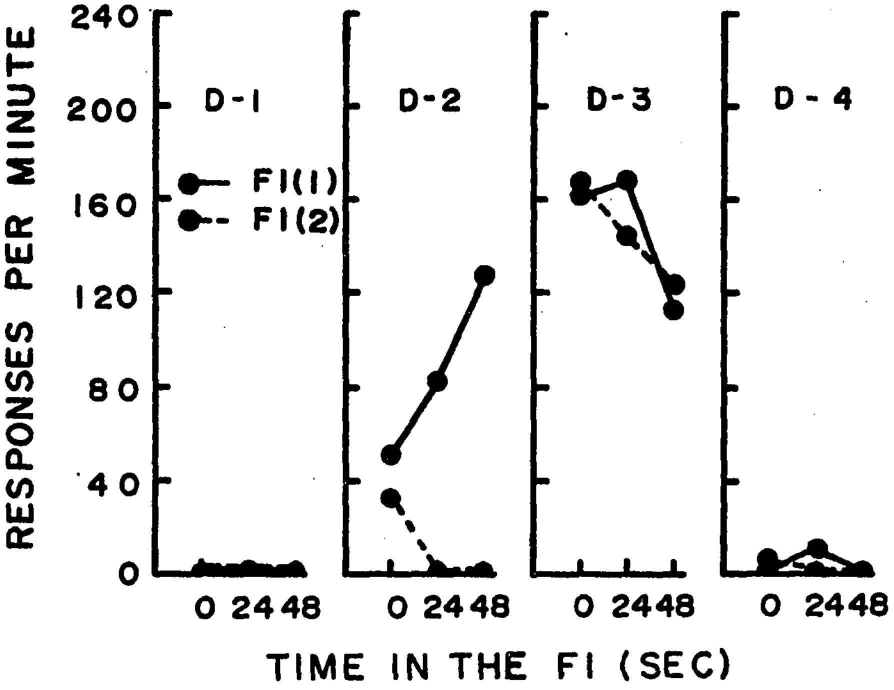
Suppression ratios as a function of the time of the onset of the CS for the fixed interval baseline schedule conditions. The open symbols depict data for the same-key group and the filled symbols depict data for the different-key group.

FIGURE 2



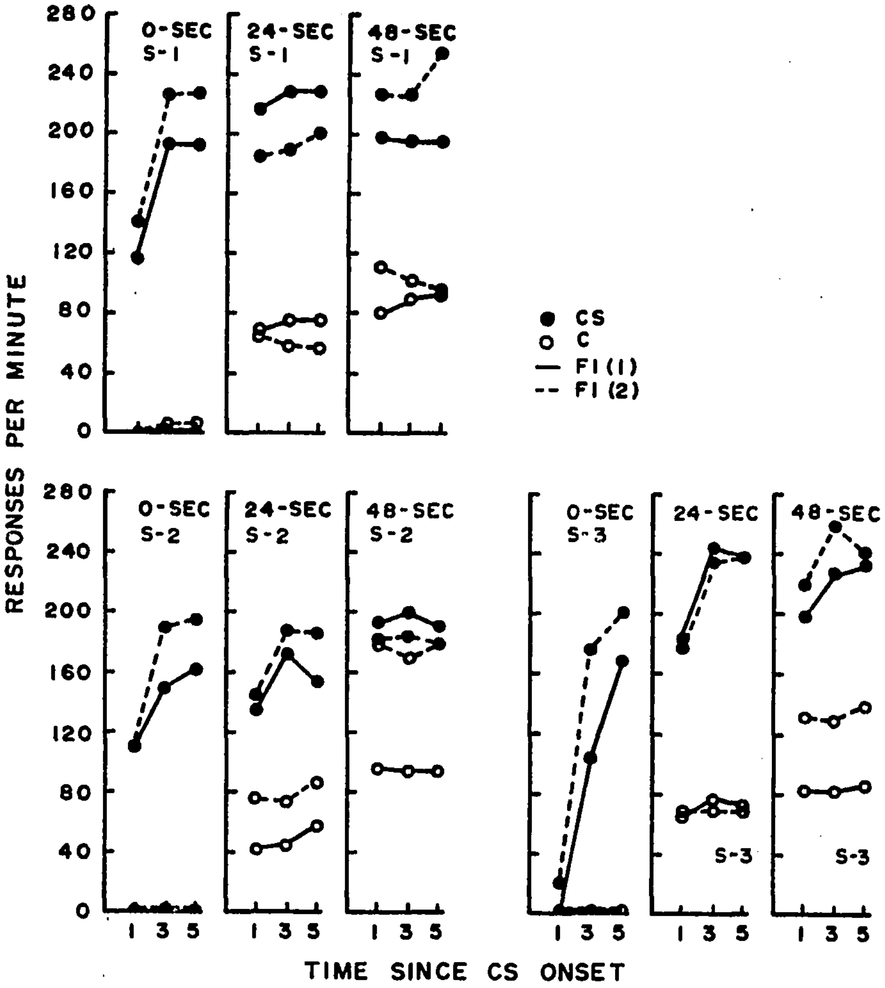
Responses per minute on the schedule key as a function of the time of the onset of the CS during CS and control periods for the fixed interval baseline conditions. The open symbols depict response rates during control conditions and the filled symbols depict response rates during the CS. Data for the same-key group are plotted in the first three panels of the top row; data for the different-key group are plotted in the last two panels of the top row and the first two panels of the bottom row; and data for the FT group are plotted in the last three panels of the bottom row.

FIGURE 3



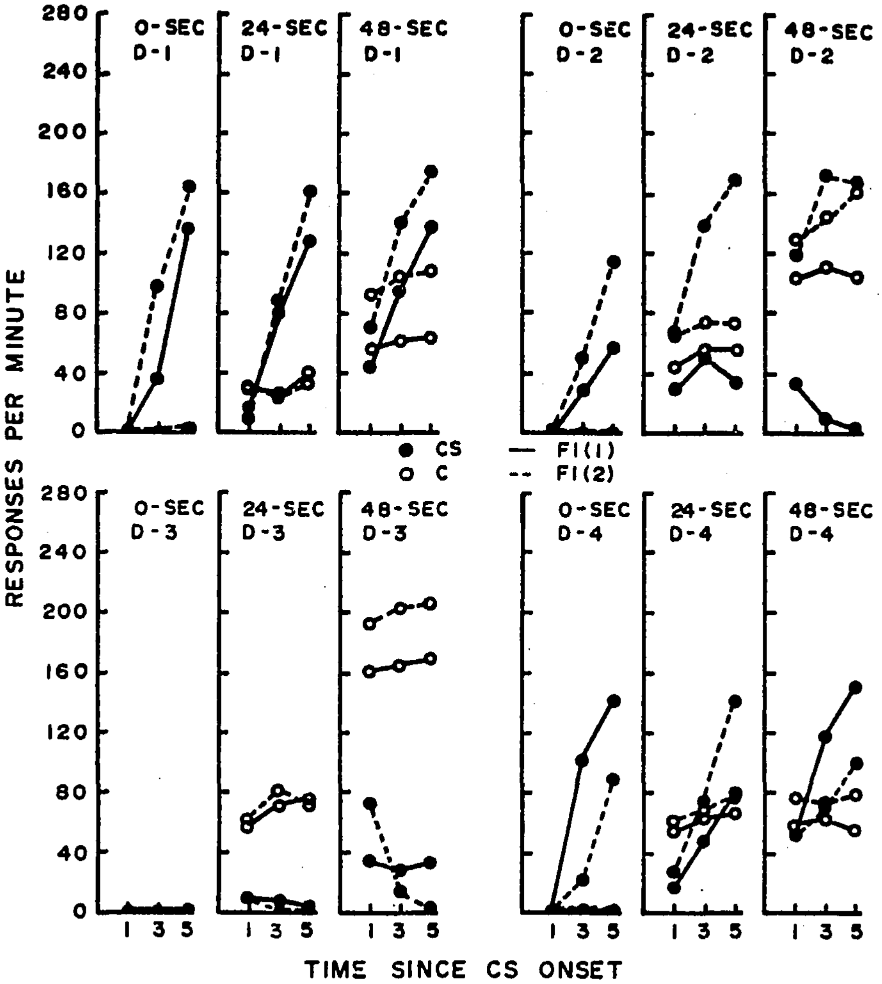
Response rate on the signal key during the CS as a function of the time of the CS onset for the different-key group. Solid lines connect the first determination of these conditions and the dashed line connect the recovery conditions.

FIGURE 4



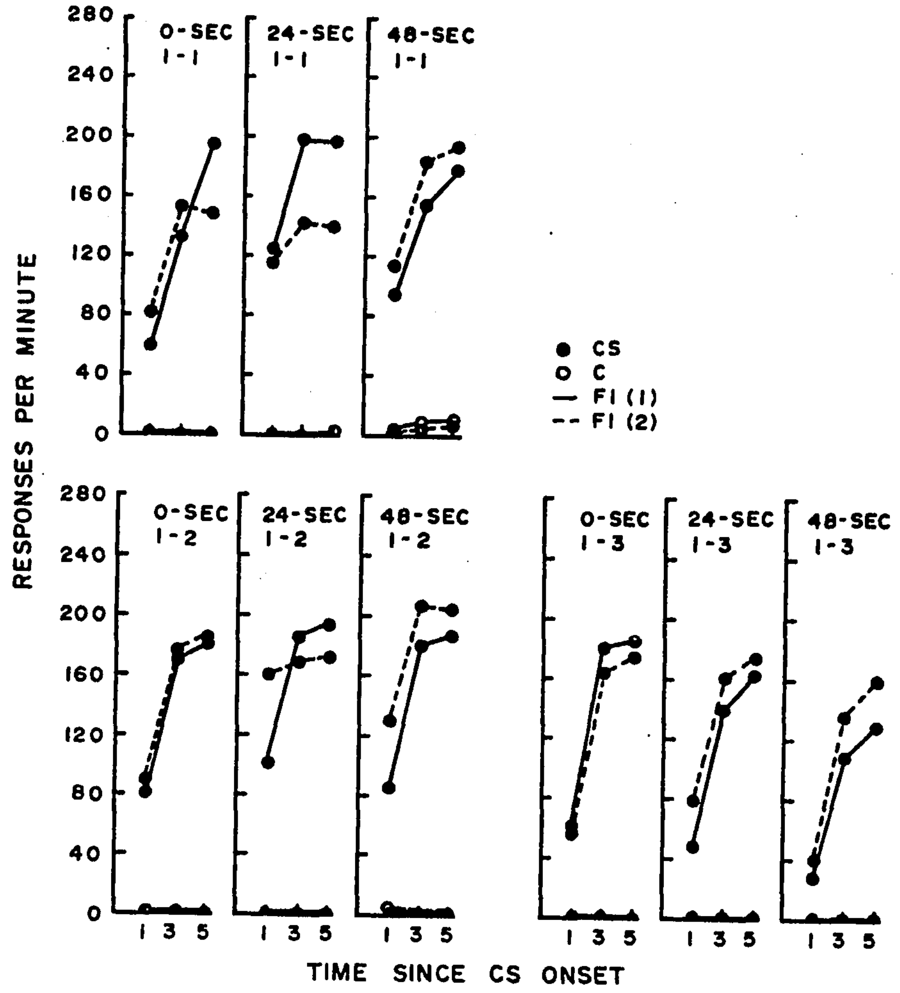
Schedule key response rate as a function of the time since CS onset (sec) with the FI baseline for the same-key group. Filled symbols depict rates during the CS, and open symbols depict rates during control periods. Solid lines connect the first determination of condition and dashed lines connect recovery conditions. Each set of panels presents data for a single subject. The first panel in each set depicts data from the 0 sec conditions, the second panel depicts data from the 24 sec conditions and the third panel depicts data from the 48 sec conditions.

FIGURE 5



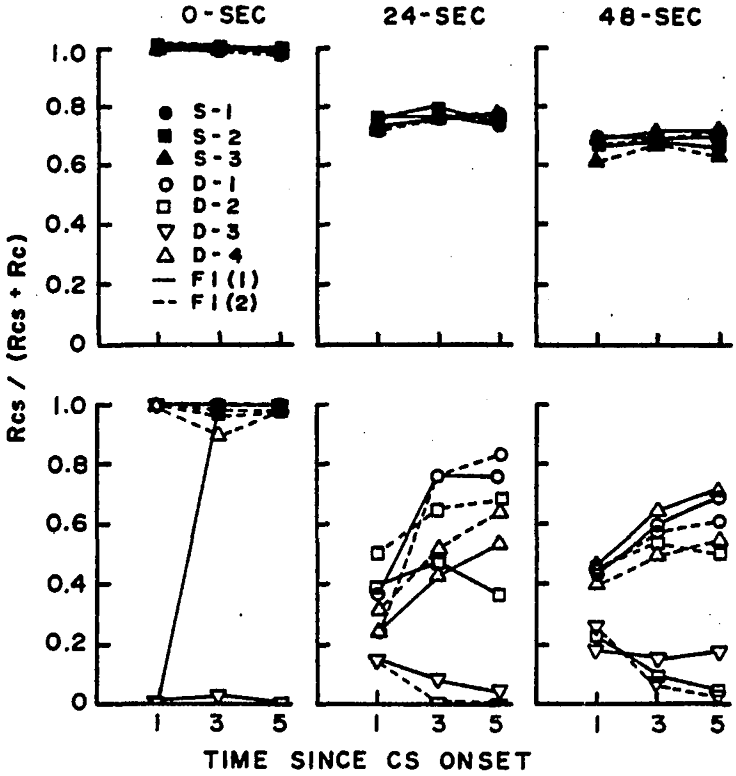
Schedule key response rates as a function of the time since CS onset (sec) with the FI baseline for the different-key group. Filled symbols depict rates during the CS and open symbols depict rates during control periods. Solid lines connect the first determination of conditions, and dashed lines connect recovery conditions. Each set of panels presents data for a single subject. The first panel in each set depicts data from the 0 sec conditions, the second panel depicts data from the 24 sec conditions and the third panel depicts data from the 48 sec conditions.

FIGURE 6



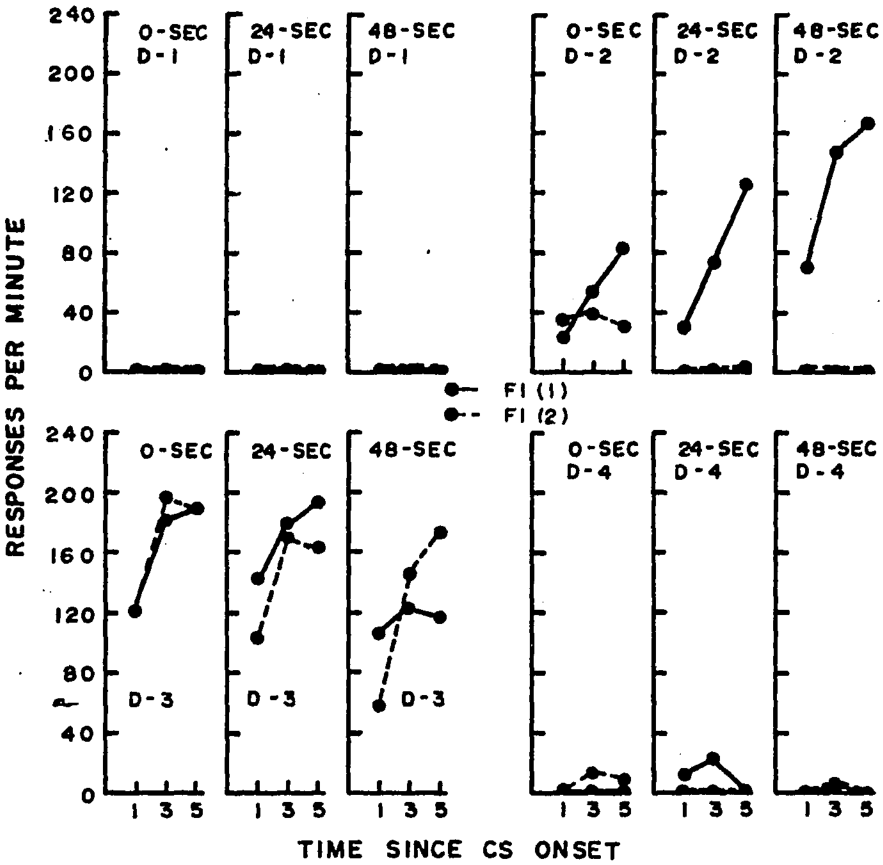
Signal key response rates as a function of the time since CS onset (sec) for the FT group. Filled symbols depict rates during the CS and open symbols depict rates during control periods. Solid lines connect the first determination of conditions and dashed lines connect recovery conditions. Each set of panels presents data for a single subject. The first panel in each set depicts data from the 0 sec conditions, the second panel depicts data from the 24 sec conditions and the third panel depicts data from the 48 sec conditions.

FIGURE 7



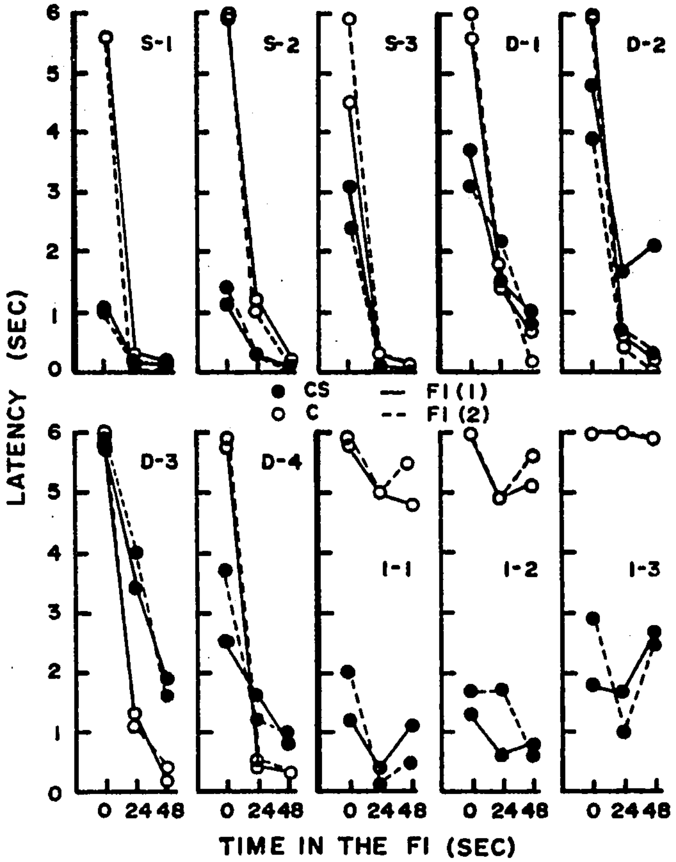
Suppression ratios as a function of time since the onset of the CS (sec) for the FI conditions. Filled symbols in the upper row depict data for the same-key group and open symbols in the lower row depict data for the different-key group. The first column shows data from the 0 sec conditions, the second column shows data from the 24 sec conditions and the third column shows data from the 48 sec conditions.

FIGURE 8



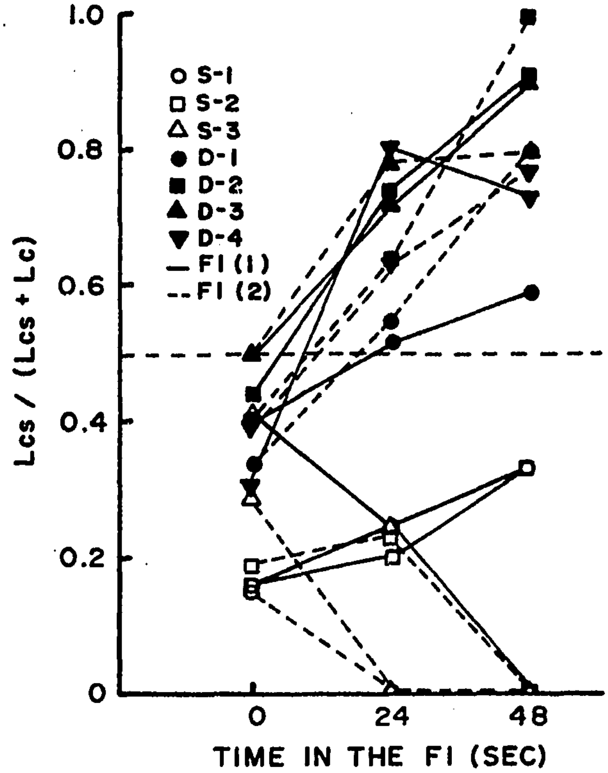
Signal key response rates as a function of the time since CS onset (sec) for the different-key group. Solid lines connect the first determination of conditions and dashed lines connect recovery conditions. Each set of panels presents data for a single subject. The first panel in each set depicts data from the 0 sec conditions, the second panel depicts data from the 24 sec conditions and the third panel depicts data from the 48 sec conditions.

FIGURE 9



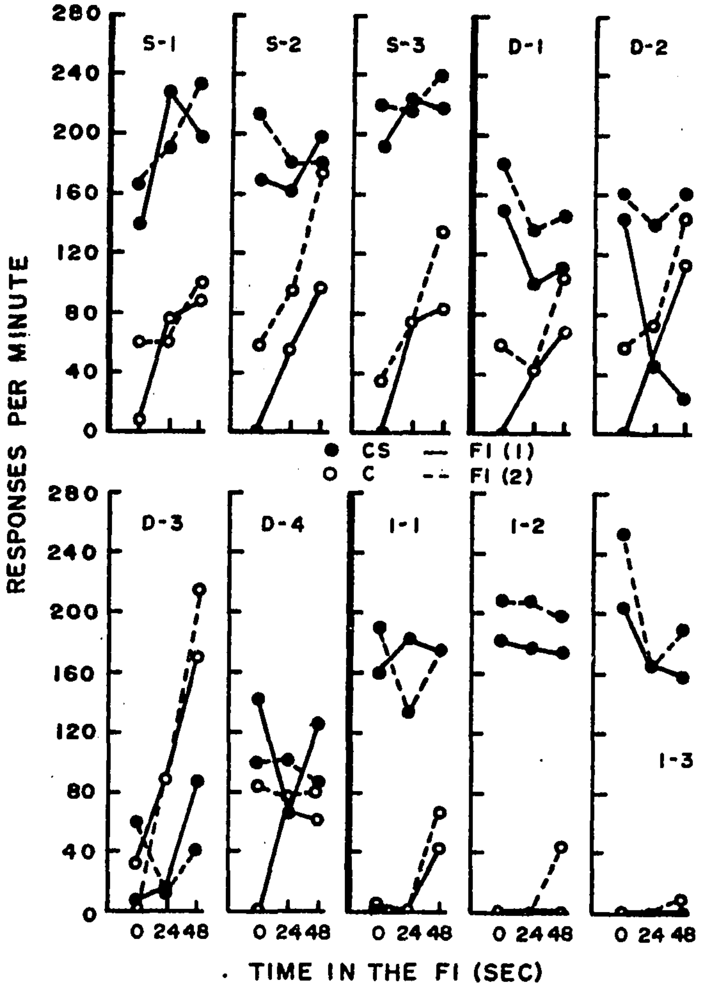
Schedule key response latencies during CS and control periods for the FI and FT conditions. Filled symbols depict latencies timed from the onset of the CS and open symbols depict latencies timed from the onset of the control period. Solid lines connect the first determination of conditions and dashed lines connect recovery conditions.

FIGURE 10



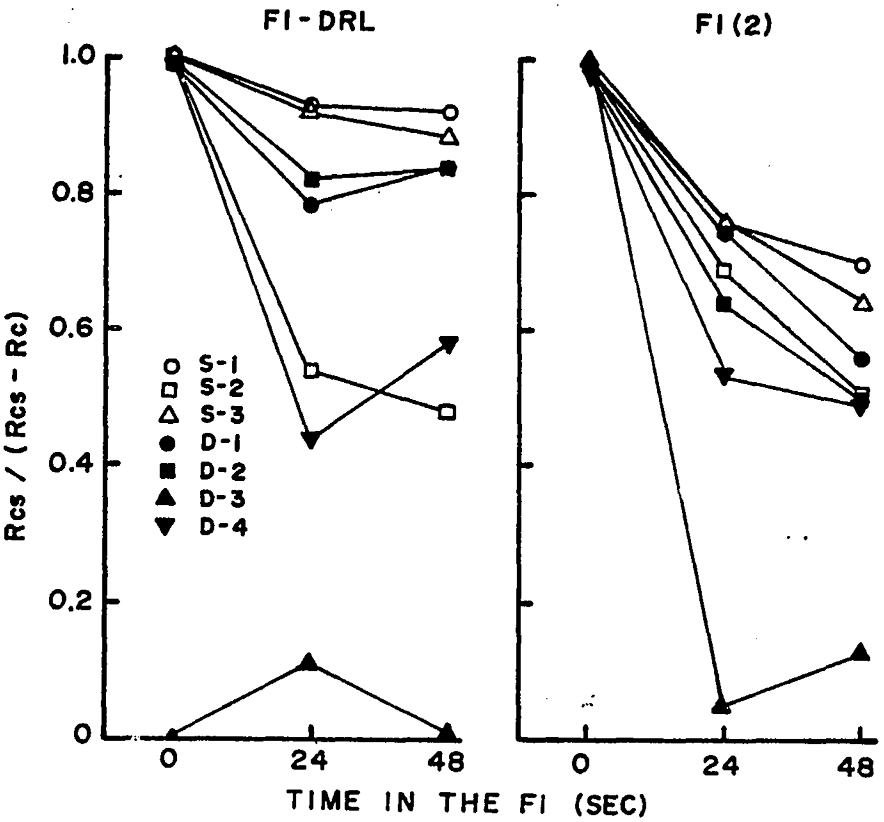
Ratios comparing response latencies during the CS to response latencies during control periods for the FI conditions. Open symbols depict data obtained with the same-key group and closed symbols depict data obtained with the different-key group. Solid lines connect first determinations of conditions and dashed lines connect recovery conditions.

FIGURE 11



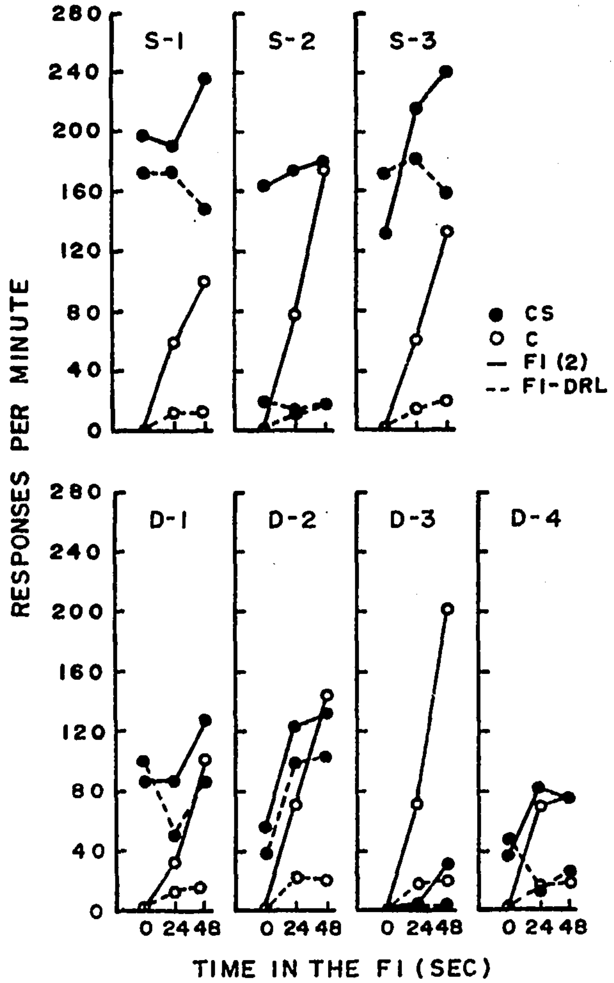
Running rates on the schedule key during CS and control periods as a function of FI and FT conditions. Filled symbols depict rates obtained during the CS and open symbols depict rates obtained during the control periods. Solid lines connect first determinations of conditions and dashed lines depict rates obtained during recovery conditions. The first three panels of the top row show data from the same-key group. The last two panels of the top row, the first two panels of the bottom row show data from the different-key group and the last three panels of the bottom row show data from the FT group.

FIGURE 12



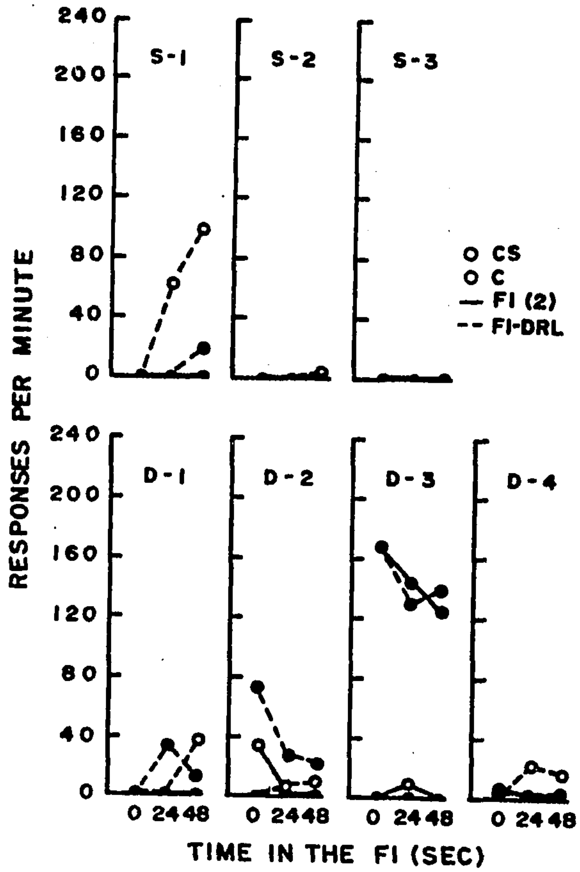
Suppression ratios as a function of the time of the CS onset for the FI-DRL and FI recovery conditions. Open symbols depict data obtained with the same-key group. Filled symbols depict data obtained with the different-key group.

FIGURE 13



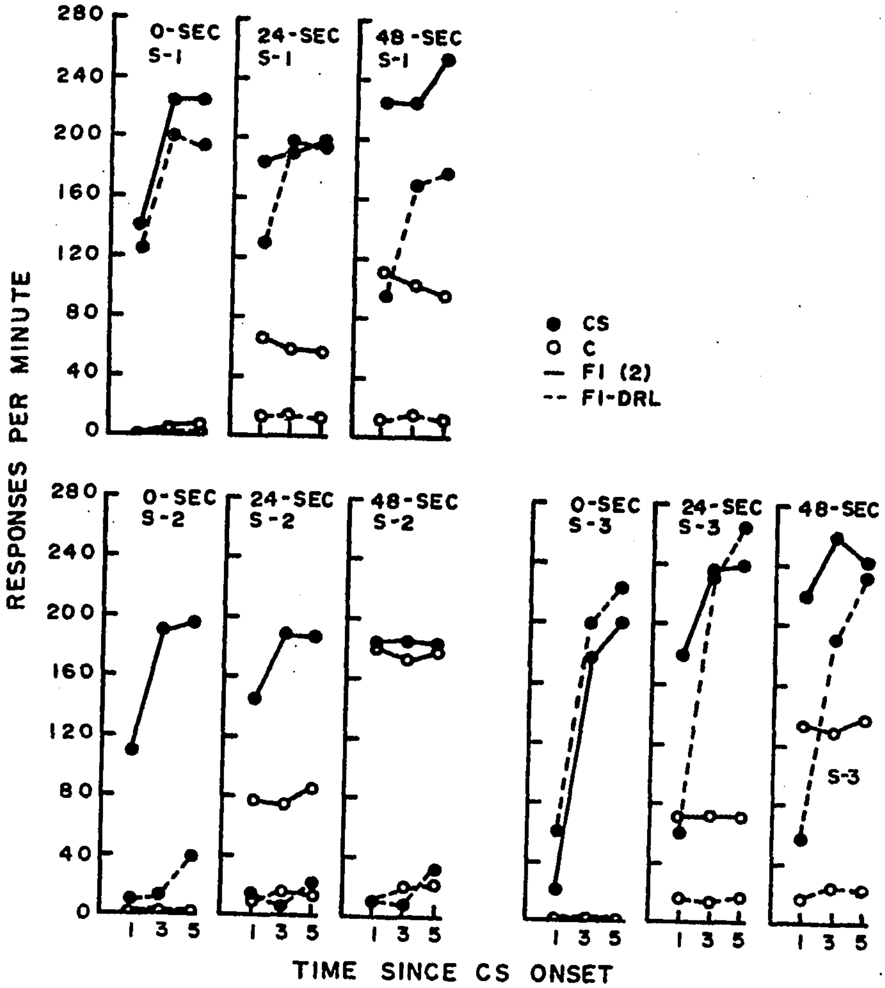
Schedule key response rates as a function of the time of the CS onset for the FI-DRL and FI recovery conditions. Open symbols depict response rates during control periods and filled symbols depict response rates during the CS. The top row presents data obtained with the same-key group. The bottom row presents data obtained with the different-key group.

FIGURE 14



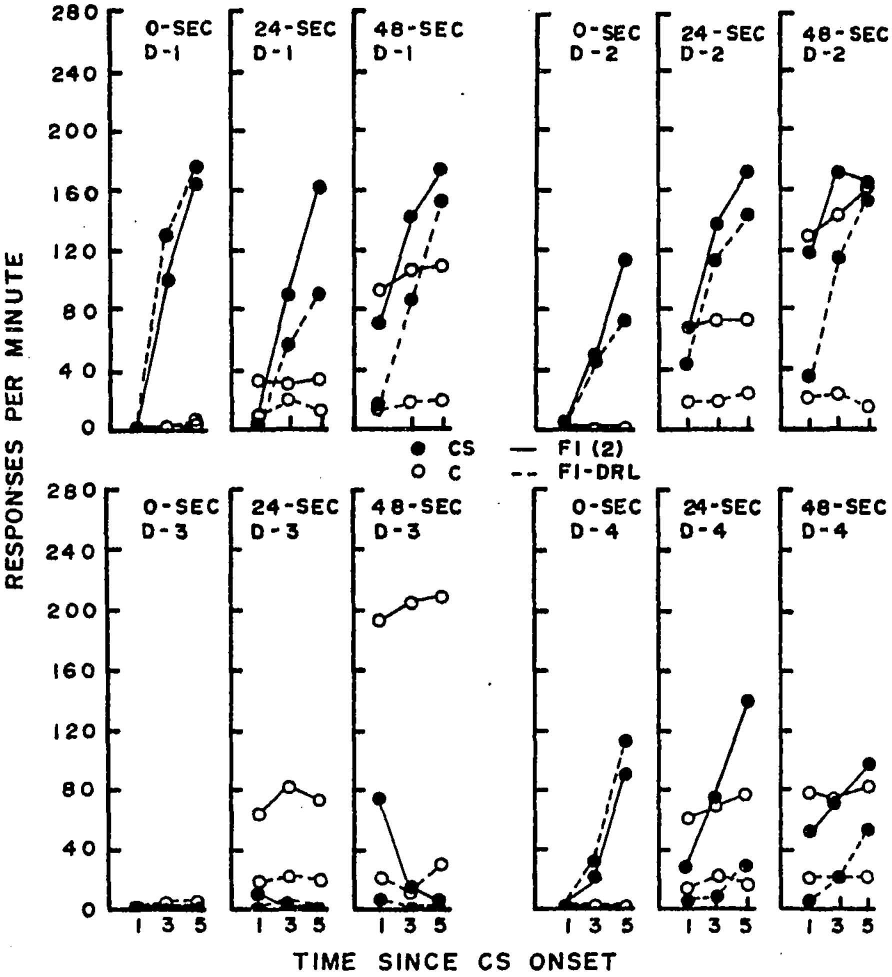
Collateral key pecks during the CS and control periods as a function of the time of the CS onset. Open symbols depict pecks during the control period and filled symbols depict pecks during the CS. Solid lines connect FI recovery conditions and dashed lines connect FI-DRL conditions. The top row shows the same-key group data and the bottom row shows the different-key group data.

FIGURE 15



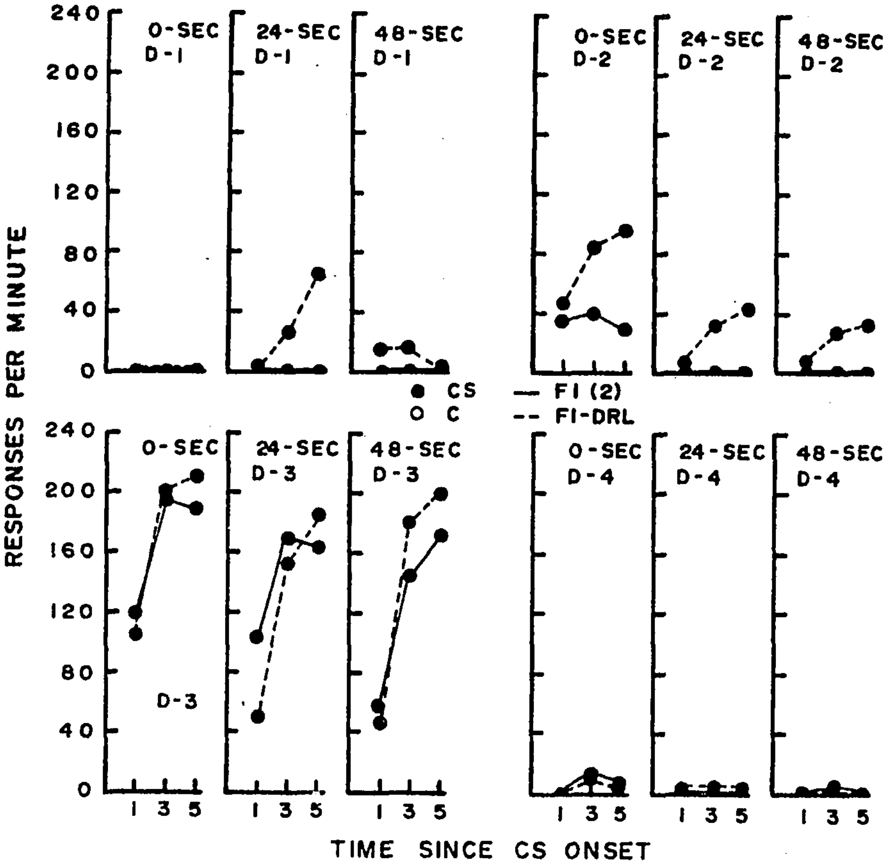
Schedule key response rates during CS and control periods as a function of the time since the CS onset for the same-key group. Open symbols depict rates obtained during control periods and filled symbols depict rates obtained during the CS. The solid lines connect FI recovery conditions and the dashed lines connect FI-DRL conditions. Each set of panels shows data for a single subject. The first panel of each set shows the rates obtained with the 0 sec conditions, the second panel shows the rates obtained with the 24 sec conditions and the third panel shows rates obtained with the 48 sec condition.

FIGURE 16



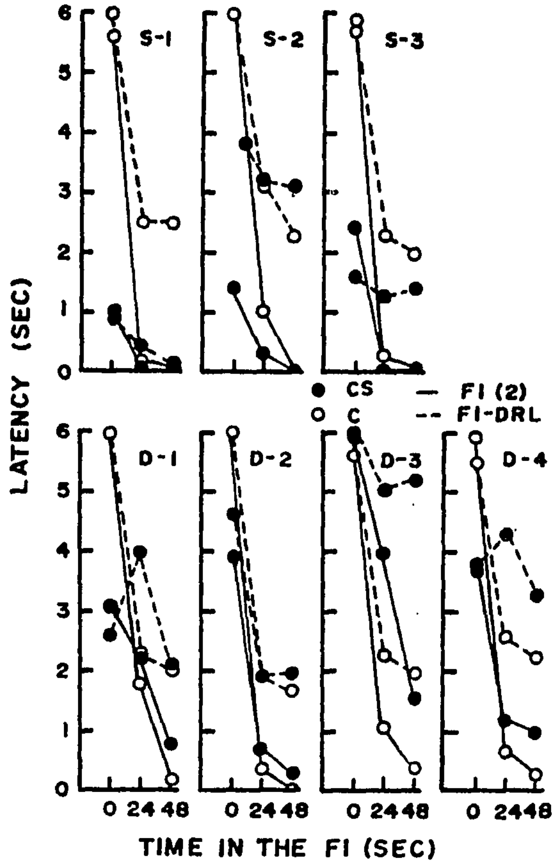
Schedule key response rates during CS and control periods as a function of the time since the CS onset for the different-key group. Open symbols depict rates obtained during control periods and filled symbols depict rates obtained during the CS. The solid lines connect FI recovery conditions and the dashed lines connect FI-DRL conditions. Each set of panels shows data for a single subject. The first panel of each set shows the rates obtained with the 0 sec conditions, the second panel shows the rates obtained with the 24 sec conditions and the third panel shows rates obtained with the 48 sec conditions.

FIGURE 17



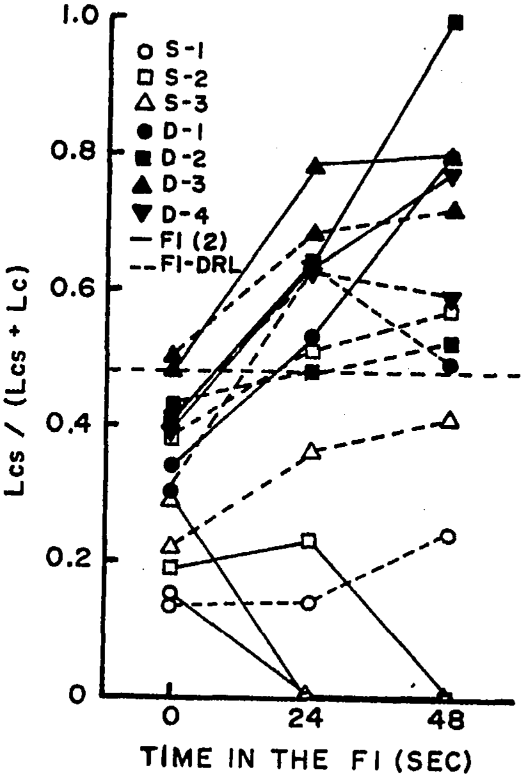
Signal key response rates during the CS as a function of the time since the CS onset for the different-key group. Solid lines connect FI recovery conditions and the dashed lines connect FI-DRL conditions. Each set of panels shows data for a single subject. The first panel of each set shows the rates obtained with the 0 sec conditions, the second panel shows the rates obtained with the 24 sec conditions and the third panel shows rates obtained with the 48 sec conditions.

FIGURE 18



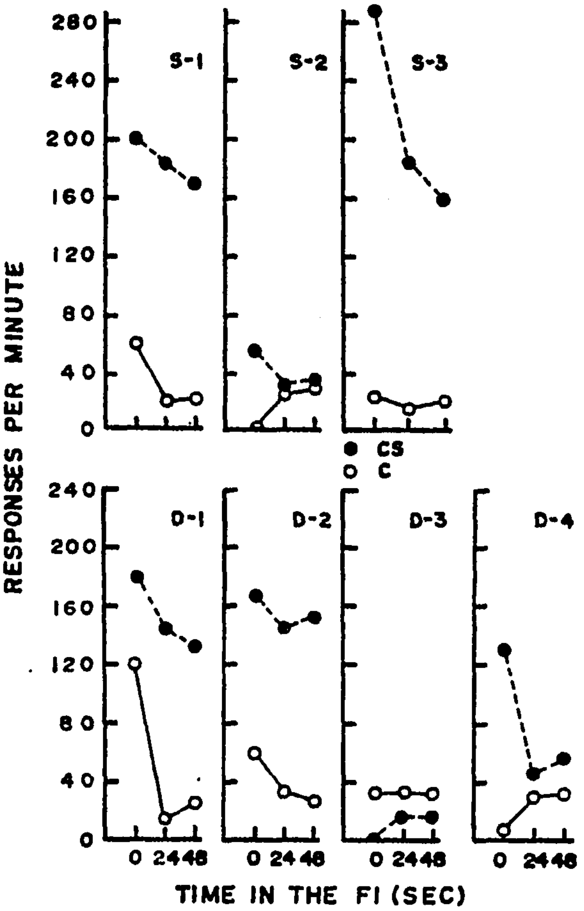
Schedule key response latencies during CS and control periods for the recovery FI and FI-DRL conditions. Filled symbols depict latencies timed from the onset of the CS and open symbols depict latencies timed from the onset of the control period. Solid lines connect the recovery FI conditions and dashed lines connect FI-DRL conditions.

FIGURE 19



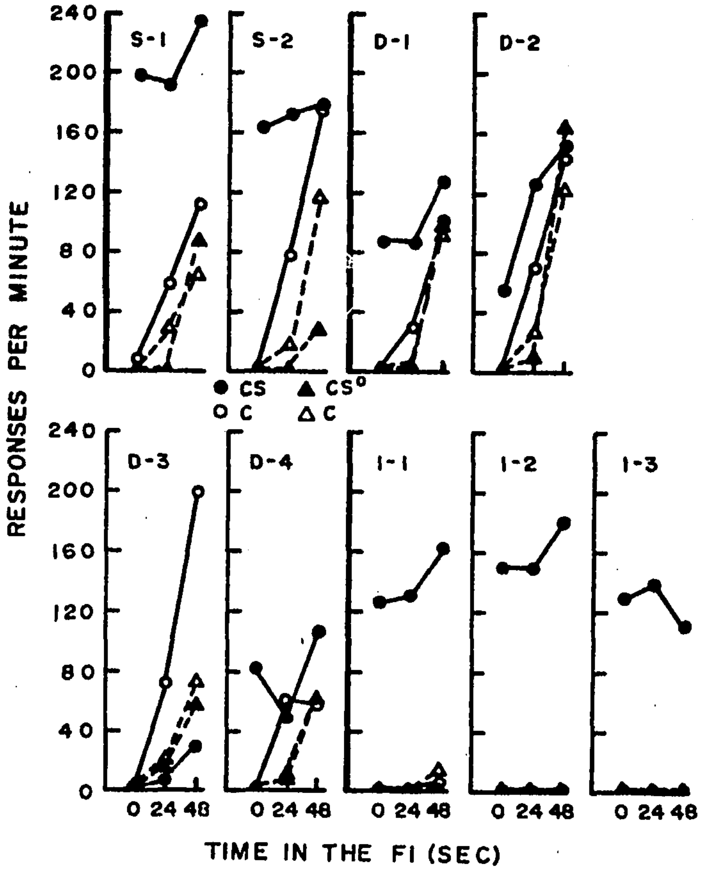
Ratios comparing response latencies during the CS to response latencies during control periods for the FI recovery conditions and for the FI-DRL conditions. Open symbols depict data obtained with the same-key group and filled symbols depict data obtained with the different-key group. Solid lines connect FI recovery conditions and dashed lines connect FI-DRL conditions.

FIGURE 20



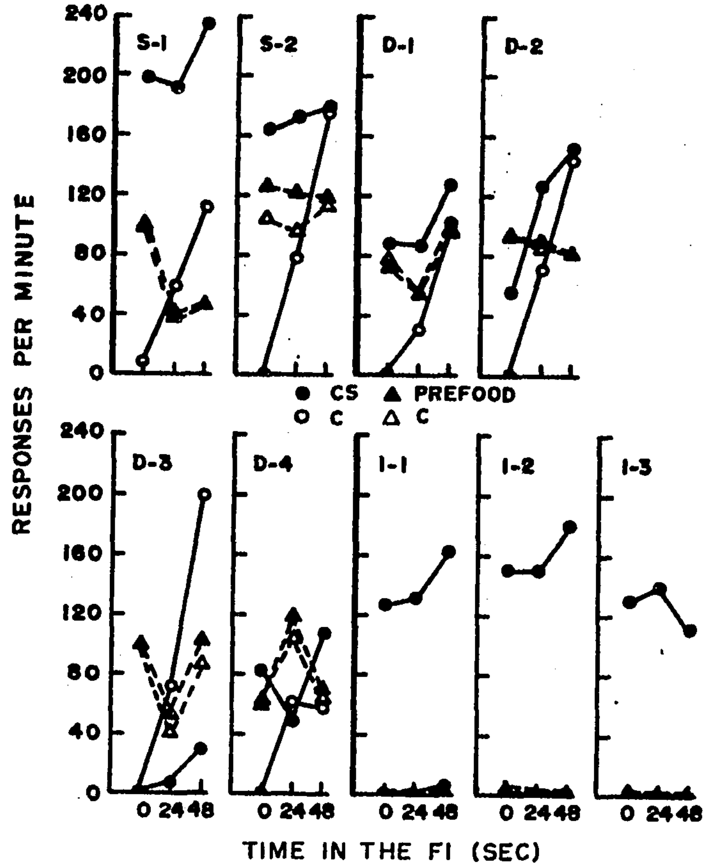
Running rates on the schedule key during CS and control periods as a function of time in the FI for the FI-DRL conditions. Filled symbols depict rates obtained during the CS and open symbols depict rates obtained during control periods. The top row shows the data of the same-key group and the bottom row shows the data of the different-key group.

FIGURE 21



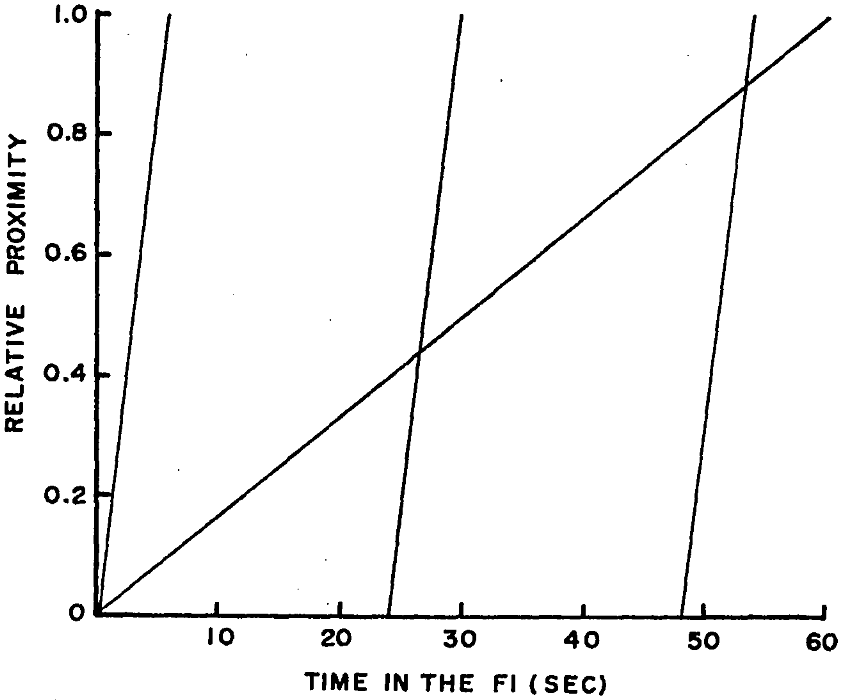
Schedule key response rates during a stimulus unpaired with food, a CS and control periods. The circles show data from conditions in which a CS was presented and triangles show data from conditions in which an unpaired stimulus was presented. Filled symbols show rates from intervals in which either a CS or a CS^0 were presented and open symbols show rates from control periods. The top row shows the data of the same-key group and the bottom row shows data of the different-key group.

FIGURE 22



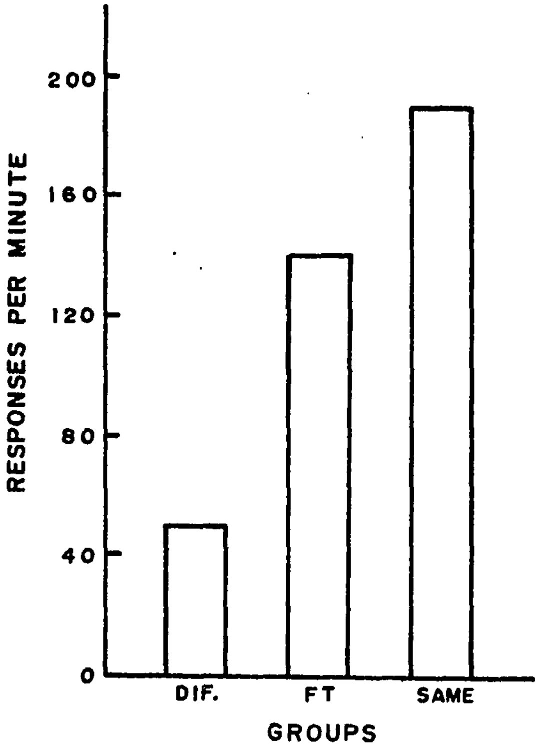
Schedule key response rates during an unsignaled prefood period, a CS and control periods. The circles show data from conditions in which a CS was presented and the triangles show data from conditions in which unsignaled food was presented. Filled symbols show rates from the CS period and the unsignaled prefood period. Open symbols show rates from control periods. The top row presents the data of the same-key group and the bottom row presents the data of the different-key group.

FIGURE 23



Relative proximity of food as a function of time in the FI.

FIGURE 24



Average response rates on the signal key for the different experimental group.