BLOCKING AND THE PREVENTION OF BLOCKING FROM THE UNCONDITIONED STIMULUS IN PAVLOVIAN CONDITIONING

By

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ABSTRACT

Seven experiments are reported which demonstrate and analyze interference with autoshaping from unsignaled USs. In Experiment 1, eight groups of 10 homer pigeons each received conditioning sessions consisting of an 880 s wait followed by a train of USs spaced 10.5 s apart, followed by a second 880 s wait. For all groups except one, one of the USs in the train was signaled by a 10 s red keylight CS. The position of this single trial in the train was varied across these groups; for the remaining group, all the USs were signaled by the CS. Conditioning of the CS was shown to be a function of the position of the CS in the train. Specifically, conditioning was achieved only when the single trial appeared at or near the beginning of the train (referred to as the trial location effect) or, when all USs were signaled by the CS.

The trial location effect was analyzed in Experiments 2 through 4 which showed that the interference from prior USs cannot be explained by any of the currently accepted explanations. Further analysis showed that the source of the interference is blocking of conditioning of the CS by the preceding USs which become established as signals of the next US.

In Experiments 5 - 7 it is shown that blocking from unsignaled USs can be prevented through prior conditioning of the CS. It is argued that this result requires a view of conditioning as producing a long term change in the associability of the CS. A recent model of conditioning which encompasses such a change in associability is reviewed. A preliminary examination of this model shows that it might provide an account for the present results.

ACKNOWLEDGEMENTS

It quickly becomes obvious to anyone working on a project the size of this dissertation that such projects must reflect the guidance and contribution of individuals other than the author. The present thesis and the author owe a debt of gratitude to many people who contributed in various ways to the development and fruition of this project. I would like to take this opportunity to thank them.

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INTRODUCTION

Classical (or Pavlovian) conditioning refers to the process by which a previously neutral stimulus becomes a signal for another, biologically significant stimulus, as a result of temporal pairings of the two stimuli. Prior to conditioning, a neutral stimulus will normally evoke a nonspecific orienting reaction in an experimental subject. Following successful conditioning, the previously neutral stimulus will evoke a reaction in the subject which is (usually) similar to the stronger reaction evoked by the significant stimulus with which the neutral stimulus was paired.

Understanding the process or processes which underlie classical conditioning has been a subject of importance to the psychology of learning for nearly a century. From the time of Pavlov's (1927) demonstration of classical conditioning in 1899 to the present day, a substantial body of research and theory has accumulated on the question of the essential conditions for establishing a previously neutral stimulus (the conditioned stimulus) as a signal for a biologically significant stimulus (the unconditioned stimulus).

The purpose of the present experiments is to further our understanding of these conditions. It has been recognized for almost 20 years that repeated temporal pairings of the to be conditioned stimulus (CS) with an unconditioned stimulus (US) are not sufficient to ensure that conditioning of the CS will occur. If USs are also presented in the absence of the CS, conditioning which would otherwise occur can be prevented even though the CS-US pairings are themselves not altered. A great deal of research over the last 15 years or so has been aimed at understanding the process by which the unsignaled USs prevent the CS-US pairing from bringing about conditioning. Furthering our understanding of this process is the specific purpose of the present experiments.

Basic conceptions in the current literature of how unsignaled USs interfere with conditioning are reviewed in the following section. Although the first experiment of the present thesis demonstrates a source of interference that is not anticipated by the existing conceptions, certain of these basic conceptions may nevertheless provide a general theory of interference that applies to this unanticipated source. The following review therefore provides necessary background for the presentation and discussion of the present results.

Review of Literature on Interference

Pavlov (1927) believed that pairing a CS with a US was sufficient to bring about conditioned responding to the CS if certain other basic conditions (such as the general health and alertness of the animal) were met. This assumption has since been referred to as the _contiguity assumption_ (Spence, 1951; Jenkins and Lambos, 1983). Research since Pavlov's time has shown, however, that CS-US pairings are not in fact sufficient to insure that conditioned responding will emerge. An important set of experiments showing the insufficiency of the contiguity assumption was carried out by Rescorla (1968a, 1968b, 1969). Rescorla demonstrated that CS-US pairings that would otherwise result in conditioning could be prevented from doing so by the addition of unsignaled USs between trials. Moreover, Williams and Williams (1969) showed that previously acquired responding could be eliminated by the addition of unsignaled USs. Because the addition of unsignaled USs leaves unchanged the number and contiguity of CS-US trials, these results show that CS-US contiguity is not solely responsible for establishing the CS as a signal and that stimuli surrounding the CS-US pairing (as well as the pairing itself) must be considered in order to understand whether CS-US pairings will render a CS a signal for the US.

Several explanations have been offered for how unsignaled USs interfere with conditioning to a CS. The first of these was proposed by Rescorla himself. Rescorla's (1969) results led him to restate the essential conditions of CS-US association in terms of the construct of contingency. Two events, such as presentation of the CS and presentation of the US, are said to be related through a (positive) contingency when the presence of one is associated with the presence of the other and the absence of one is associated with the absence of the other. Pavlov's (1927) belief that CS–US contiguity was sufficient for the CS to become a signal for the US fulfilled only the first half of these requirements. The addition of unsignaled USs can remove the contingency between the CS and the US, and thus prevent the CS from becoming a signal of the US.

Another phenomenon which showed that CS–US contiguity was not sufficient to produce conditioning was Kamin's (1969) demonstration of blocking. Kamin showed that a previously conditioned CS, A, could block acquisition of conditioned responding to a subsequently added stimulus, B. Although B preceded and overlapped the US (ie. was contiguous with it), it did not acquire the ability to evoke a conditioned response.

The blocking phenomenon and the effects of CS–US contingency have each stimulated a substantial body of theory and research aimed at establishing the essential conditions for the formation of an association between a CS and a US. Psychologists have been reluctant to accept Rescorla's (1969) proposal that CS–US contingency is the essential condition of association for at least two reasons. First, blocking occurs even though in the blocking procedure stimulus B, the subsequently added stimulus, covaries perfectly with presence and absence of the US, and is therefore in a contingent relation with the US. Second, contingency is a statistical concept requiring the accumulation of events occurring at different times over the course of conditioning. Conditioning, however, is characterized by gradual trial by trial changes in behavior. It would be desirable to have a trial by trial account of conditioning which did not require the statistical summation of events over long periods, but nevertheless was capable of accounting for the effects of contingency on conditioning (Rescorla and Wagner, 1972; Jenkins and Lambos, 1983).

Current theoretical conceptions of the conditioning process may be viewed as an attempt to account for the apparent importance of CS-US contingency (as demonstrated by interference from unsignaled USs) without abandoning Pavlov's (1927) contiguity assumption (Jenkins and Lambos, 1983). These theories may be placed in one of two broad categories, competition theories and comparison theories. Competition theories (eg. Rescorla and Wagner, 1972; Mackintosh, 1975) share the assumption that unsignaled USs interfere with conditioning by conditioning some other stimulus, usually the context or background. This other stimulus then competes with the CS for associative strength. Comparison theories (eg. Gibbon, 1981), on the other hand, deal with the effects of unsignaled USs by postulating that the rate of US delivery in the CS is compared to the rate of US delivery in the experimental setting, and responses to a CS appear when the rate during the CS is sufficiently higher than its rate in the experimental setting. Examples of both types of theories are reviewed below.

There are several theories based on competition. The first competition theory to explicitly address Pavlovian conditioning was proposed by Rescorla and Wagner (Rescorla and Wagner, 1972; Wagner and Rescorla, 1972). The central concept of the theory was that of competition between concurrent stimuli for a limited quantity of associative strength, or signal value. According to the Rescorla-Wagner theory, a given US supports a limited amount of conditioning. The degree to which a CS will acquire signal value or associative strength is a function of the difference between the current signal value of the CS (together with the signal value of all other concurrent stimuli) and the maximum value supportable by the US. As the CS approaches the maximum level, conditioning to the CS becomes complete.

With two additional assumptions, the Rescorla-Wagner theory can account for both blocking and the effects of unsignaled USs on conditioned responding. One assumption is that the strength of a compound CS is the sum of the strengths of its components. The other is that the context of the learning situation, or the background, is a conditionable stimulus like any other. Given these assumptions, the equations of the theory can account for both blocking and contingency effects as follows. In blocking, the sum of the compound stimulus consisting of _A_, the preconditioned stimulus, and _B_, the subsequently added neutral stimulus, is equal to the maximum level supported by the US on the very first _AB_-US pairing by virtue of the previous conditioning of _A_. Because _A_ is already fully conditioned, and the value of _B_ is zero, the sum of the elements in the compound is maximal for the US from the very first _AB_-US pairing. Because no discrepancy exists between the strength of the compound and the maximum level, the pairings do not condition _B_ which, therefore, remains neutral. The equations of the theory thus neatly account for blocking without changing the underlying importance of CS-US contiguity for conditioning.

This account of blocking also predicts the disruptive effects of unsignaled USs on the acquisition and maintenance of conditioned responding. According to the theory, the presentation of the US without the CS will condition the background more strongly than the presentation of a US accompanied by a CS. To the extent that the CS signals the US, the background will be protected from conditioning by the US. Because the background or context (_X_) is a conditionable stimulus present at the time unsignaled USs are presented, the context acts like a blocking stimulus. The equations of the theory make the same prediction with regard to blocking whether the blocking stimulus is a discrete CS or the context of conditioning. The Rescorla-Wagner theory is thus able to account for both the blocking phenomenon and the effects of unsignaled USs, and does so without abandoning the essence of Pavlov's assumption that CS-US contiguity was sufficient to bring about learning about the CS.

An important property of the Rescorla-Wagner theory is that it is a single process competition theory. In a single process theory, signal value (V) is the only property of the CS that is altered by conditioning. There are, however, other competition models which also account for the effect of unsignaled USs but which differ from the Rescorla-Wagner theory in that they are dual process models (Zeaman and House, 1963; Sutherland and Mackintosh, 1971; Mackintosh, 1975). In a dual process theory, conditioning alters the attention getting value, or salience, of the stimulus as well as its signal value. Dual process models were originally invoked to account for results from discrimination learning studies where it was shown that concurrently present stimuli interact with one another in learning trials, a phenomenon called stimulus selection (Mackintosh, 1974). The phenomena of blocking and overshadowing, for example, demonstrate that conditioning to a stimulus over trials depends on more than the constant physical properties of that stimulus and the reinforcement schedule associated with it. Several researchers (Mackintosh, 1975; Pearce and Hall, 1980) have attempted to account for the effects of unsignaled USs by treating these effects as examples of stimulus selection and analyzable through a dual process approach. A relatively recent example of a dual process conditioning theory is Mackintosh's (1975) attentional theory. Mackintosh's theory postulates that pairings of a CS with a US result in two changes in the CS. One is the associative strength of the CS, as with the Rescorla-Wagner theory. But Mackintosh's theory claims further that conditioning trials also bring about a change in the associability (ie. the salience or attention getting value) of a CS, and specifies rules for the direction of that change. Because the associability of the CS (which may be thought of as the degree to which a subject will attend to the CS) determines in part the change in associative strength of that CS on the next trial, Mackintosh's theory provides two components which jointly determine the change in strength of a CS as a result of CS-US pairings.

Mackintosh's theory accounts for blocking and for the effects of unsignaled USs in the following way. The rules for changing the associability of a CS stipulate that whenever a CS predicts an otherwise unexpected US, the associability of the CS will increase. Conversely, the associability of a CS will decrease whenever the CS "signals no change in reinforcement from the level expected on the basis of other events" (Mackintosh, 1975, p. 287). In blocking, CS _A_ already predicts the US at the time when stimulus _B_ is added, so the associability of _B_ rapidly declines until it is unconditionable. Hence _B_ is blocked.

Blocking of the CS due to a decline in associability is also said to occur in the case of unsignaled USs. Here, if unsignaled USs are presented at a sufficient rate, the background, X, becomes a better predictor of US delivery than the CS, A, so the associability of the CS declines, and it does not condition. In contrast to the Rescorla-Wagner theory, changes in associative strength are mediated by changes in associability, as well as occurring as a direct consequence of reinforcement and nonreinforcement.

Mackintosh's theory is nevertheless a type of competition theory. The competition is not for a limited pool of signal value, as with the Rescorla-Wagner theory, but between concurrently available stimuli for salience or associability. On reinforced trials, the relatively stronger stimulus undergoes an increase in associability and the relatively weaker stimulus loses associability. Thus stimuli compete with each other, and in most circumstances only one of several available CSs will come to evoke conditioned responding.

Other types of dual process learning theory have been offered (Pearce and Hall, 1980; Wagner, 1978, 1984). The distinctions between these models and Mackintosh's theory, although not unimportant, do not warrant elaboration for the present purposes. Rather, the distinction between single and dual component competition models is the important issue at this point. The experiments presented in the present thesis specifically address this issue, and the distinctions that are brought out in this review will guide the interpretaton of the data presented in the body of this work.

Not all models of Pavlovian learning assume that the CS competes with other elements, however. A very different view of signal learning, which also addresses how unsignaled USs interfere with the effect of a CS-US pairing, is provided by Scalar Expectancy Theory or SET (Gibbon, 1977; Gibbon and Balsam, 1981; Jenkins, Barnes, and Barrera, 1981). SET looks to comparison, rather than competition, to understand the effects of unsignaled USs on conditioning. SET is perhaps most easily approached through a discussion of trial spacing effects.

It has been demonstrated in several Pavlovian conditioning arrangements that the rate at which subjects learn to respond to the CS is determined in part by the temporal spacing of trials. Long intertrial intervals lead to more rapid acquisition of conditioned responding (on a per US basis) than do short ones (Prokasy, 1960, 1965; Gormezano and Moore, 1969; Gibbon, Locurto and Terrace, 1975; Gibbon, Baldock, Locurto, Gold, and Terrace, 1977). This result has been under investigation for several decades, as no theory or theory of signal learning would be complete if it could not account for an effect as basic as trial spacing.

SET (scalar expectancy theory) provides one account of trial spacing effects. According to this theory, two independent expectations for an unconditioned stimulus are formed during conditioning. One of these is the expected rate of US occurrence in the experimental setting or context. The other is for the rate of US delivery during the CS, or signaling stimulus. According to scalar expectancy theory, the speed of acquisition of a conditioned response is a direct function of the ratio (expectancy during CS to overall expectancy) of these two independently established expectancies. Thus long intertrial intervals lead to rapid acquisition of conditioning because for a conditioned stimulus of a given duration, longer intertrial durations lead to a lower overall expectancy for the US. This makes the ratio of expectancy during the CS to overall expectancy larger, leading to the faster emergence of conditioned responding.

From the point of view of this discussion, what is interesting about scalar expectancy theory is that, according to this theory, adding CS-US pairings to a conditioning experiment should have the same effect on acquisition as adding unsignaled USs between trials (Jenkins, et al., 1981). Both operations would be expected to retard conditioning, and to the same extent, because the overall expectancy is determined by the average rate at which USs are presented. Specifically, expectancies are calculated as mean rates of US occurrence, both for the conditioning session as a whole (CS and nonCS periods) and during the presence of the CS (CS periods only). Adding either a CS—US pairing or an unsignaled US does not change the average rate of US occurrence in the presence of the CS, but it does change the average rate in the session. Hence the ratio of expectancies is reduced and conditioning is retarded.

Scalar expectancy theory thus provides an answer to the problem of understanding the effects of unsignaled USs in classical conditioning studies which is rather different than the one provided by the Rescorla—Wagner or Mackintosh theories. Whereas these latter theories look to competition between stimuli, either for a limited pool of signal value or for conditionability, SET points toward the comparison of expectancies for the US between the signal and the overall context (see Jenkins, et al., 1981 or Gibbon, 1981, for a fuller discussion).

It follows from the preceding discussion that these two classes of theories can be empirically distinguished on the basis of whether or not adding signaled USs disrupts conditioning to the same degree as adding unsignaled USs. The evidence on this point is mixed. Jenkins et al. (1981) conducted several studies which did not produce evidence of a difference between signaled and unsignaled USs, providing support for SET. These results have been supported and extended in experiments by Jenkins and Lambos (1983) and by Balsam (1984). Durlach (1983), on the other hand, was able to show that signaling intertrial USs with a tone stimulus significantly reduced the disruptive effects of USs added between CS-US pairings.

This concludes the review of the existing literature regarding the interference with conditioning which results from unsignaled US presentations. In the following section, the bearing of the present experiments on this issue is examined.

Introduction to the Present Experiments

The first experiment in this thesis was motivated (in part) by a desire to test the adequacy of scalar expectancy theory as an account of interference from unsignaled USs in Pavlovian conditioning experiments. According to SET, the proportion of USs which are signaled by the CS is not a variable of importance because it has no effect on the expectancy ratio. On the other hand, both the Rescorla-Wagner theory and Mackintosh's theory predict that this variable has important effects on conditioning. The proportion of USs which are signaled was manipulated in Experiment 1. In addition, SET is an averaging theory. The expectancies for the US that make up the expectancy ratio are presumed to reflect average values for the session, and local variations in US rate with respect to the temporal location of trials do not, according to SET, play a role in determining the degree or rate of acquisition (Gibbon and Balsam, 1981). This prediction was also tested in Experiment 1 through manipulations in the local (ie. immediately preceding) rate of US presentation with respect to trials.

The experimental arrangement employed in the studies to be reported here is the autoshaping preparation (Brown and Jenkins, 1968). In this arrangement a spot of light is projected onto a hinged plastic key prior to the delivery of mixed grain to a food-deprived pigeon (<u>Columba livia</u>). When these pairings of keylight and food (CS and US) occur in a context in which no other CSs or USs are presented, pecking directed at the spot rapidly emerges. This pecking has been demonstrated to be a form of conditioned responding with properties similar to those shown by conditioned responding in other Pavlovian conditioning arrangements (Williams and Williams, 1969; Hearst and Jenkins, 1974).

CHAPTER 1

EFFECT OF THE TEMPORAL LOCATION OF A CS-US PAIRING IN A TRAIN OF CLOSELY SPACED UNSIGNALED USs.

Experiment 1

Introduction

According to Scalar Expectancy Theory (SET), the proportion of USs in a conditioning session that are signaled by the CS makes no difference with regard to the expected rate of acquisition of conditioned responding to the CS. Moreover, the local temporal context of a trial with respect to other USs is not expected to affect the speed of acquisition. This is contrasted with predictions made by the Rescorla-Wagner formulation. According to this theory, the higher the proportion of USs which are signaled by the CS, the greater the level of conditioning to the CS is expected to be. Furthermore, the local context of the trial is expected to play a role because it is expected to affect the signal value of the context at the time of the trial.

In Experiment 1, an unusual conditioning arrangement was employed in which all the USs in each session were presented in a closely spaced temporal train. For all groups except one, only one of the USs was signaled by the CS, with the position in the train of the CS-US pairing differing across these groups. For the last group, all the USs in the train were signaled by the CS. According to the account of interference due to unsignaled or signaled USs provided by SET, all the groups would be expected to acquire at about the same rate. According to the Rescorla-Wagner theory, or Mackintosh's theory, on the other hand, those groups in which the CS was presented early in the train should show the highest level of conditioning. The groups for which the CS-US pairing was presented later in the train would be expected to suffer greater interference owing to the greater opportunity for conditioning of the context (or for the associability of the context to be increased) prior to the CS-US pairing. Finally, the group for which all the CSs were signaled should show the strongest acquisition, because in that group there was the least opportunity for contextual conditioning. Experiment 1 examined these predictions.

Method

Subjects. Subjects were 87 adult racing homer pigeons obtained from local breeders. All subjects were maintained on *ad libitum* weight for at least two weeks after they were received at the colony. They were deprived to 80% of *ad libitum* weight prior to receiving any experimental treatment. Subjects were housed between experimental sessions in a single windowless colony room. The colony was illuminated between 7:30 AM and 10:30 PM. The temperature was maintained at 21 degrees centigrade.

Apparatus. The same apparatus was used for each experiment reported in this thesis. At no time over the course of the experiments reported here was any change in the apparatus introduced. Six modified Lehigh Valley animal conditioning chambers were used. The exterior dimensions were 56.5 cm x 40.5 cm x 42.5 cm. The interior of each chamber was partitioned into two sections by an intelligence panel which measured 30.5 cm high x 34.8 cm wide. The larger of the two sections measured 30.5 cm high x 34.8 cm wide x 34.9 cm deep, but a 7.6 cm high platform was inserted, raising the floor and reducing the height to 22.9 cm. The pigeon subjects were placed in this part of the chamber. On the front of the intelligence panel were two 3.2 cm square hinged plastic keys which activated a microswitch when pressed with a force of more than 15 N. The two keys were located 1 cm apart, 12 cm above the platform floor and 4 cm from the left and right inside walls of the chamber respectively. In the center of each key was a 0.7 cm diameter circle which could be illuminated with red light. The right key was covered with tape and not used in any experiment.

Four centimeters above the platform floor, centered on the panel, was a 5 x 7 cm opening through which mixed grain could be made available via a solenoid-operated hopper. The hopper opening contained a 28 volt GE 1829 light bulb which was lit whenever the hopper was activated. An infrared phototransmitter and receiver 1 cm behind the hopper opening and on either side of it allowed recording when a subject's head was in the hopper. Houselighting was achieved by two GE 1829 bulbs on the intelligence panel. The bulbs were located 3 cm from the ceiling of the chamber and 2 cm apart. White noise was always delivered at 70 dB (measured in the center of the chamber) through a three-inch speaker attached to the rear of the panel. Ventilating fans operated continuously in each chamber to provide fresh air.

The scheduling of events was achieved using a Commodore 8032 PET computer. Responses to the left key or the photocell beam were measured in real time by a machine language polling routine which was called from a BASIC program. Listings of all the programs used, which were written by the author, are available upon request.

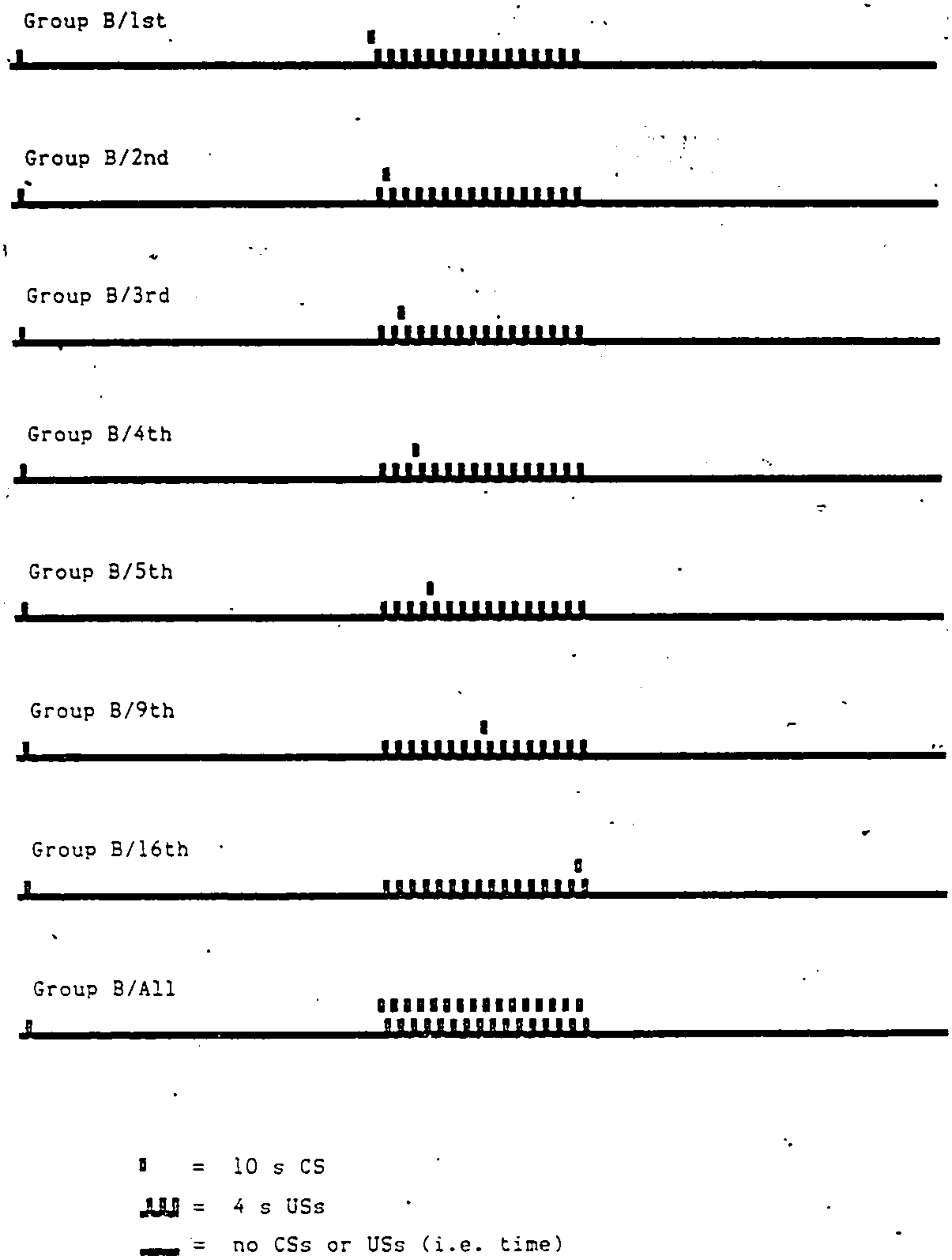
Hopper Training Procedure. The same hopper training procedure was used for every experiment reported here. The procedure consisted of two stages. In the first stage, the hopper was raised before the pigeon was placed in the chamber. The houselights and white noise were turned on and the subject was placed in the box. As soon as the photocell beam inside the hopper opening was broken, a timer for that chamber was started, which held the tray up for 15 s. Following this, the hopper was lowered for 20 s and then raised until 15 s after the beam was broken again. From this point on the duration for which the hopper was held up was changed to 4 s, and 18 more USs were given. The hopper always remained up until the timer was activated so that a subject could not miss a feeding by failing to approach the hopper. A total of 20 USs was thus given, the first two of 15 s duration and the remaining 18 of 4 s duration. Fifteen seconds after the 20th feeding, the houselights were turned off and the subject remained in the blacked-out chamber until the end of the training session. Subjects were given a maximum of one half hour to take all the USs. Following either this period or immediately after all six subjects had fed 20 times, subjects were removed from the chamber. Every chamber operated independently of all the others during this procedure. Five sessions of this phase of hopper training were given on consecutive days.

During the second phase of hopper training, the procedure was changed so that the timers which ended the USs were activated as soon as the hopper was raised. Thus USs were now scheduled independently of the subject's behavior. The time between feeder offset and the onset of the following feeding remained 20 s. The program recorded the latency to enter the feeder for all USs and printed these data following the session. This phase of the procedure was run for 3 sessions on consecutive days. Any subject that did not eat reliably was removed from the experiment at this point, as well as other subjects (chosen at random) as needed to bring the total number of birds in the experiment down to 80 subjects.

Acquisition _Treatments_: Figure 1 shows the procedures used in Experiment 1. Subjects were divided at random into eight groups of 10 subjects each. The part of the procedure common to all subjects was as follows. Subjects were placed in the chambers with only the ventilation fans and white noise on. Approximately 5 seconds after the last subject had been put into the conditioning chamber, the houselights were activated and the hoppers were simultaneously raised and held up for 10 seconds. This unsignaled feeding served to define the start of the first waiting period in the session. It had another function as well. In autoshaping experiments it is not uncommon for subjects to display a rigid or frozen posture at the start of conditioning sessions, which is presumed to be an emotional response to the stresses of handling and transport to the chamber. The first feeding served to reduce the amount of time subjects spent in this state.

Following the first 10 s feeding, an 880 s wait (houselights on, no CSs or USs) was scheduled. At the end of this wait, a series or train of 16, four-second USs was presented. The time between the offset of one US and the onset of the next was 10.5 s (see Figure 1). This series is hereafter referred to as the train of USs. Following the train of USs, a second 880 s wait was scheduled. At the end of this period, the houselights were turned off and subjects were removed from the boxes. All 6 boxes were programmed to

Figure 1. The design used for Experiment 1. Time is read along the bottom axis, and the shaded patterns represent CSs and USs. The Figure is not drawn to scale.


Group B/1st
Group B/2nd
Group B/3rd
Group B/4th
Group B/5th
Group B/9th
Group B/16th
Group B/All
= 10 s CS
= 4 s USs
= no CSs or USs (i.e. time)

operate identically and simultaneously for all sessions.

The groups differed in terms of which US in the train of USs was preceded by a CS. The CS was presented by illuminating the small circle on the response key with red light for 10 seconds. The offset of the CS always occurred simultaneously with the onset of the US (feeder up). For seven of the eight groups, only one CS per daily session was scheduled. For Group B/1st (read "CS presented before 1st US in train") the CS signaled the first US in the train of USs. For Group B/2nd, the CS was presented .5 seconds after the end of the first feeding in the train, and signaled the second US in the train of USs. Groups B/3rd, B/4th, B/5th, B/9th, and B/16th also received a single CS at the positions indicated by the designation of the group. An eighth group, Group B/All, received a CS before each of the 16 USs. When compared with those groups that received a single CS at different locations, this group provides information on the effect of signaling other reinforcers in the train on the acquisition of responding to a CS at a given position in the train.

Sixteen training sessions were run on consecutive days. The dependent variables of interest were the number of trials[1] presented before the acquisition criterion was met (the same as the number of sessions for all groups except for B/All), and the rate of responding to the CS over sessions. The criterion for acquisition of conditioned responding was at least one response to the key-light CS on 4 out of 5 consecutive trials. The acquisition score was the trial number at the beginning of the set of trials on which the criterion was met. Gibbon and Balsam (1981) reported that this criterion was more reliable than the criterion of number of trials presented before the first response.

Results

Hopper Training. By the end of the second phase of hopper training, all but 3 subjects were eating grain from the hopper over 95% of the time. The 3 subjects which did not eat reliably were removed from the experiment at this point, along with 4 other randomly chosen subjects in order to obtain 80 naive subjects to be divided into eight groups of ten subjects each.

Acquisition. The number of subjects in each group that met the acquisition criterion is given in Table 1. A Chi-squared test based on acquired vs. not acquired X group was highly significant, $X^2(7) = 53.33$, $p < .01$. Examination of Table 1 shows that Groups B/1st and B/ALL acquired fully, Group B/2nd showed moderate acquisition, and all other groups showed little acquisition, accounting for the significant result. There were no significant differences among

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[1] The term "trial" has been used ambiguously in the learning literature. To avoid confusion, in this thesis the term trial is used only to mean "CS—US pairing", where both CS and US are presented. Unsignaled US presentations, and nonreinforced CS presentations, are not referred to as trials.

Table 1

Acquisition scores from Experiment 1

Group	% Subjects acquired	Median acquisition score
B/1st	100	2
B/2nd	70	2
B/3rd	20	2.5
B/4th	10	1
B/5th	10	2
B/9th	0	-
B/16th	10	14
B/All	100	2

acquisition scores for those subjects that did acquire.

Figure 2a shows the rate of responding to the CS over sessions for all groups other than Group B/All, which is considered separately. Figure 2b shows the total number of responses made to the CS for the 16 sessions of the acquisition phase for the same groups shown in Figure 2a. It is clear from these data that the position in the train of the signaled US had a large effect on the development of pecking to the CS. In particular, Groups B/1st and B/2nd showed rapid development of responding to the CS while none of the other groups acquired the conditioned response of pecking to CS. Groups B/3rd, B/4th, and B/5th did show some responding in sessions 2 through 5, but responding was not sustained and disappeared by session 6. The data in Figure 2a were subject to a multivariate profile analysis of repeated measures (Bock, 1975; Morrison, 1976). The analysis revealed a significant effect of CS location, $F(6,63) = 10.73$, $p < .01$, session, $F(15,49) = 11.86$, $p < .01$, and a significant group x sessions interaction, $F(90,284) = 1.56$, $p < .01$. Post hoc tests revealed no significant differences in performance between Groups B/1st and B/2nd, nor among Groups B/3rd, B/4th, B/5th, B/9th, and B/16th.

Total responses over sessions (shown in Figure 2b) were analysed by a stepwise curvilinear regression of response totals on the number of USs which preceded the CS (Group B/ALL was excluded from this analysis). Both the

Figure 2a. Response rate to the CS over sessions, Experiment 1. Group B/All is not shown in the Figure.

Figure 2b. Mean total responses to the CS for each of the groups in Experiment 1 that receieved a single CS per session.

Figure 2a

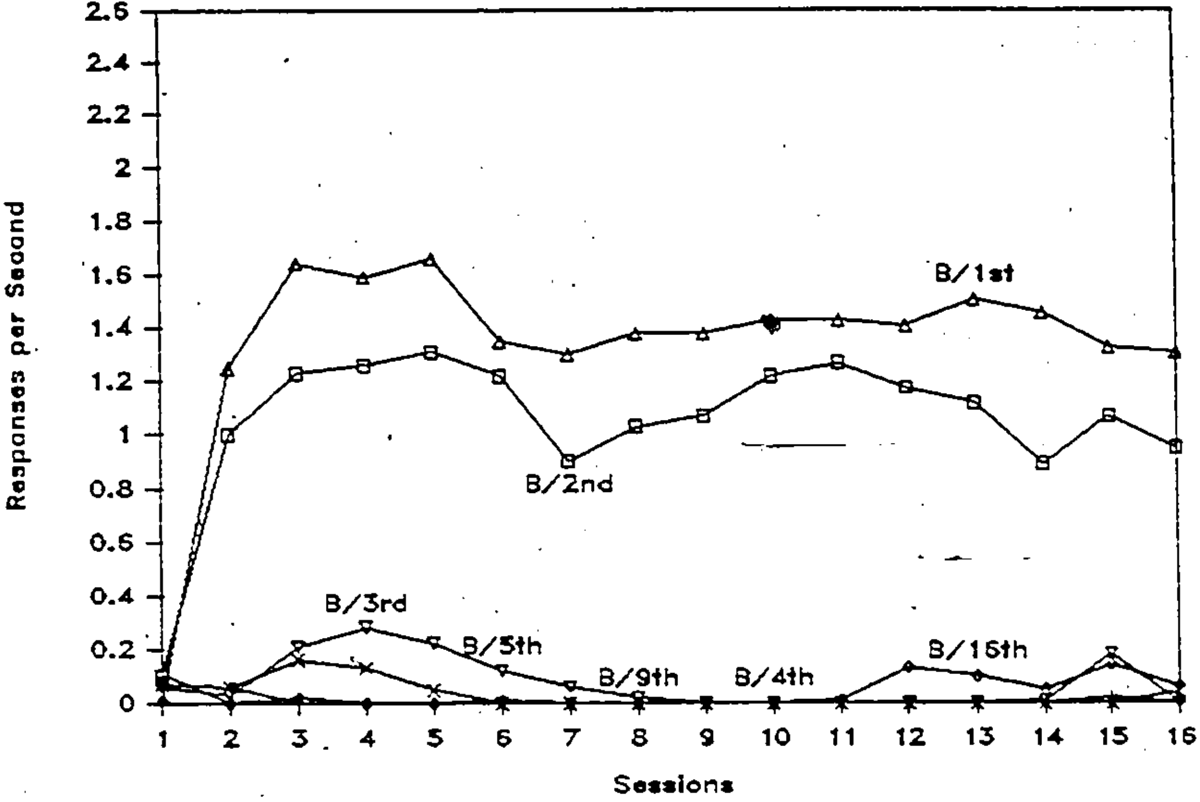
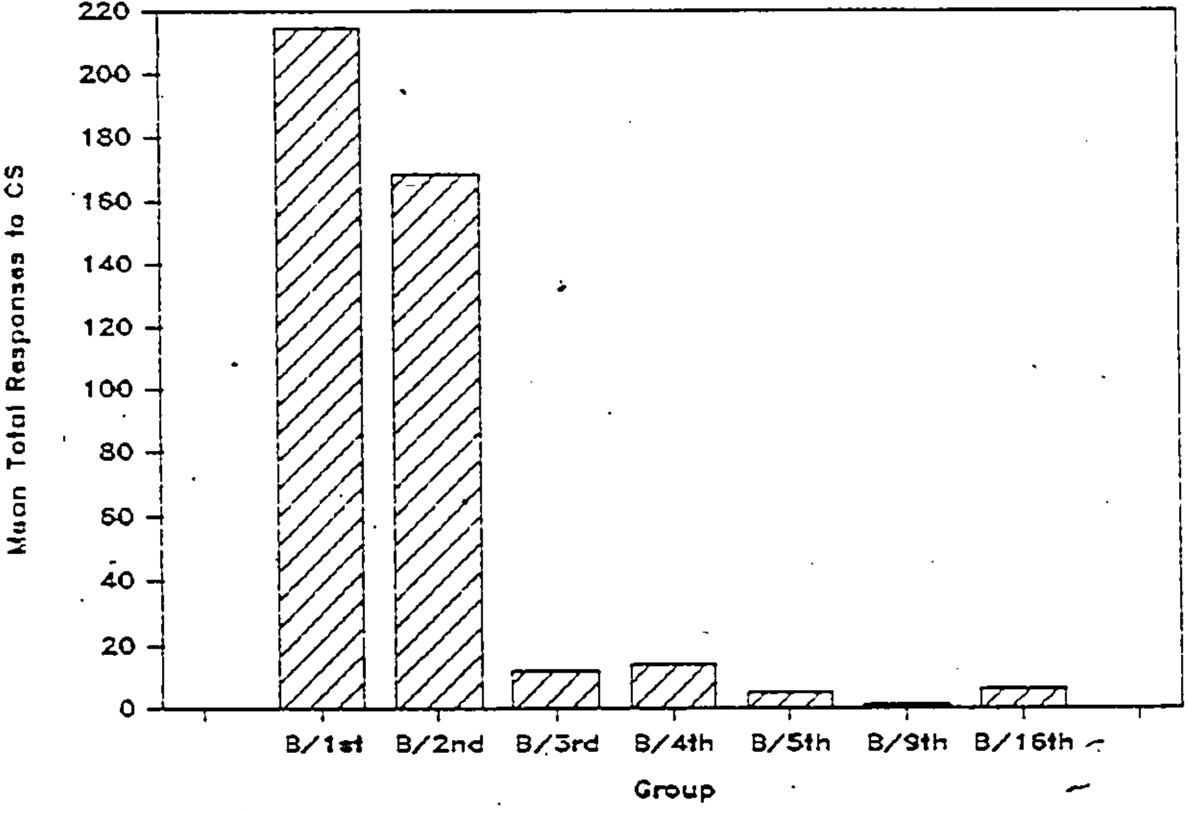


Figure 2b



linear and quadratic trends were significant, linear trend, $F(2,47) = 6.56$, $p < .01$, quadratic trend, $F(2,47) = 18.76$, $p < .01$. The quadratic equation accounted for 44.4% of the total variance in response totals. The decline in responding as the CS was moved into the block over groups is significantly curvilinear, as can be seen from inspection of Figure 2b.

Figure 3a shows responding over sessions to CSs for Group B/All in the same positions in the train where the CS was scheduled for ~~the other~~ 7 groups. These data were obtained within-subjects rather than between-subjects, as in Figure 2a. For Group B/ALL, CSs at every position were strongly responded to, even where no conditioned responding was measured in the associated group that was given only that CS (compare, for example, position 9 vs. Group B/9th). Figure 3b shows total responses to the CS at the same positions shown in Figure 3a. It is clear from this figure that the CS at position 1 evoked more responding than CSs at the other seven positions. This difference was significant based on a paired t-test between the total responses to the CS at position 1 and pooled total responses to CSs at all other positions, $t(9) = 2.45$, $p < .05$.

Within-session response patterns could be assessed only for Group B/ALL because all other groups received only a single CS per daily session. The within-session pattern of conditioned responding for Group B/ALL appears to have

Figure 3a. Response rate to the CS at positions 1, 2, ..., 16 over sessions, Group B/All, Experiment 1. Data are within-subjects.

Figure 3b. Mean total responses to the CS at positions 1, 2, ..., 16 for Group B/All in Experiment 1. Data are within-subjects.

Figure 3a

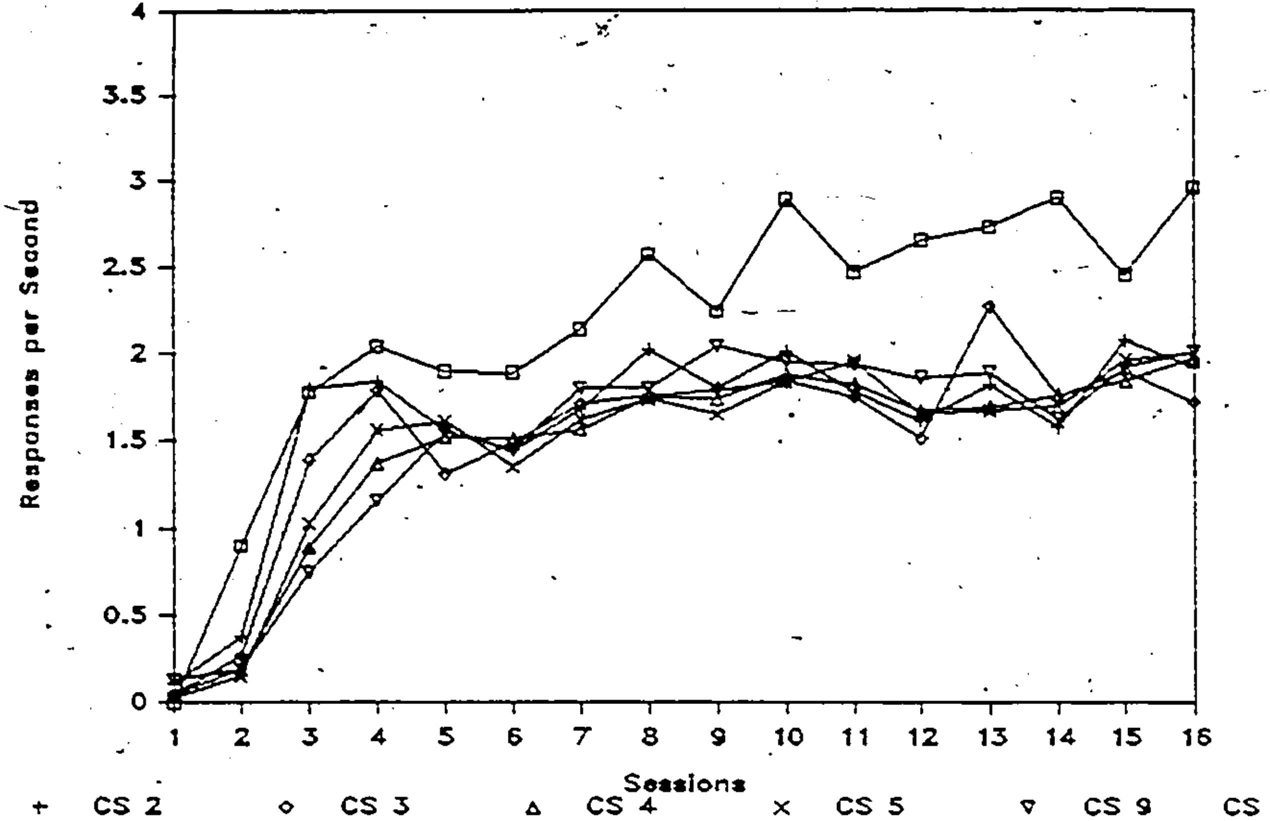


Figure 3b

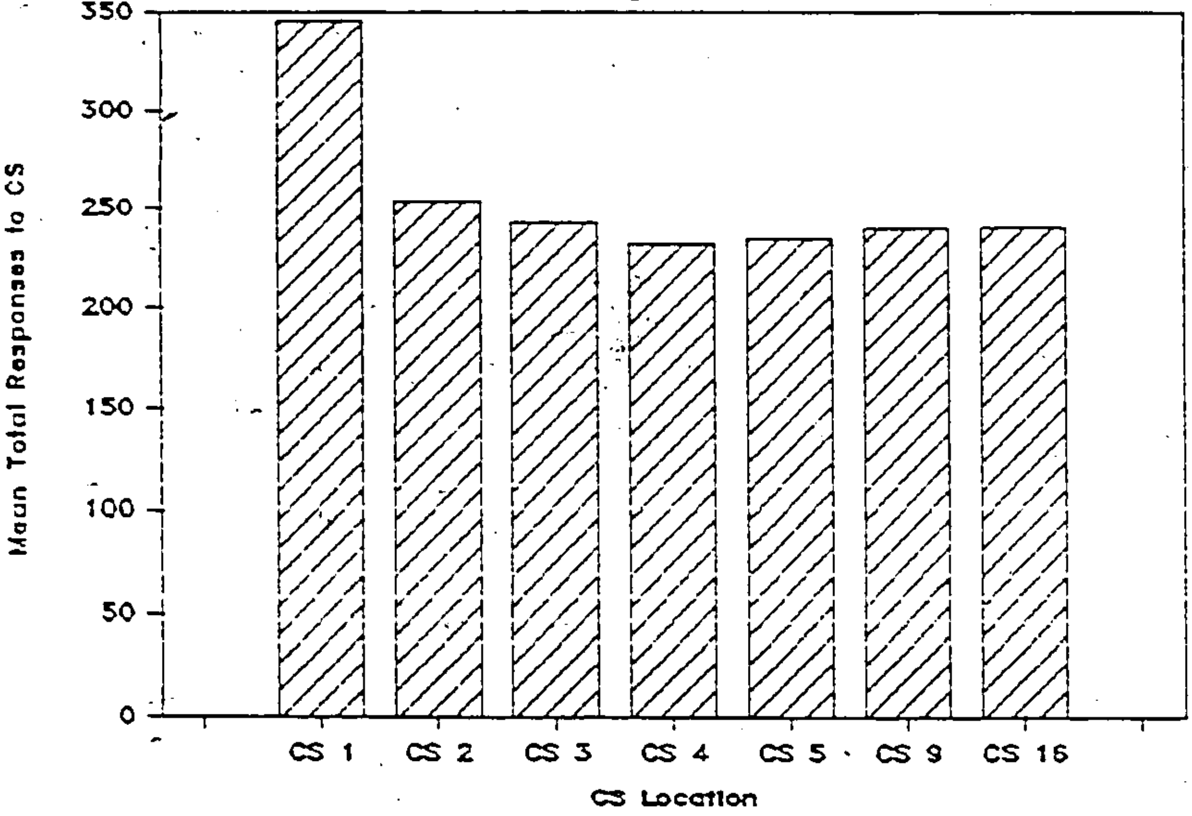
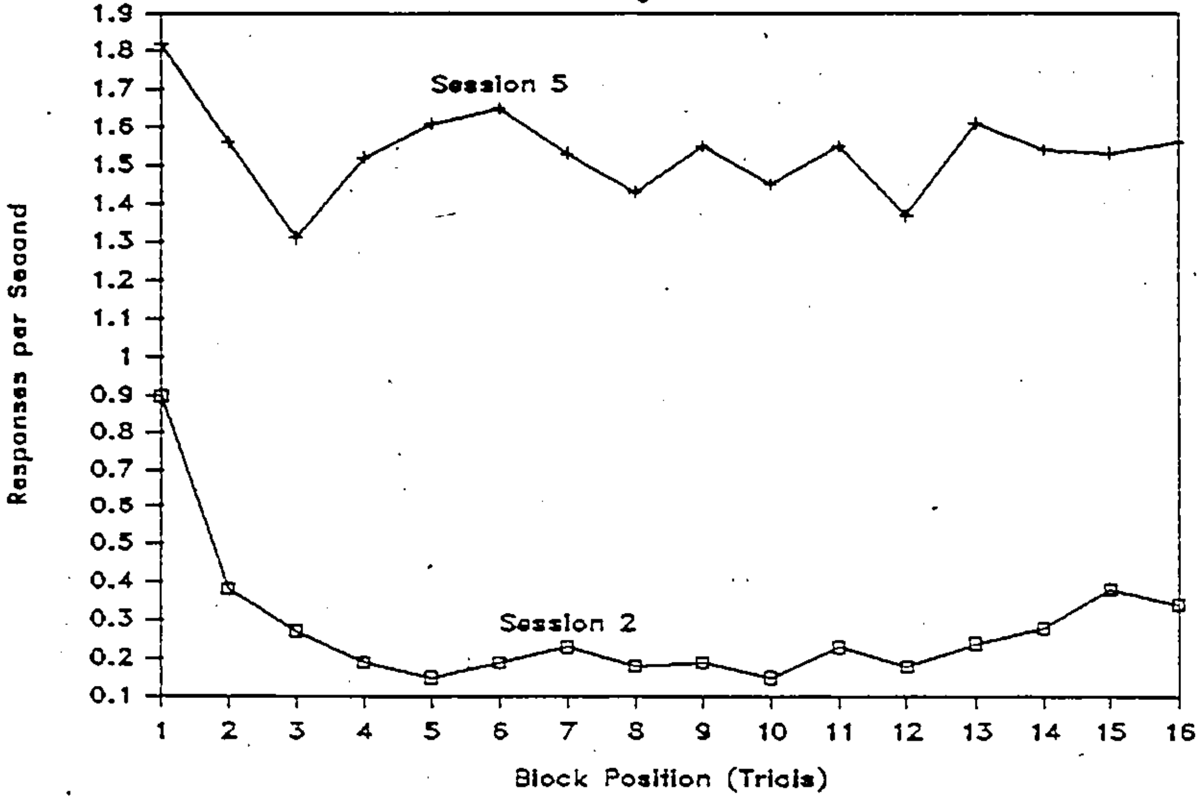


Figure 4. Within-session response in Group B/All from sessions 2 and 5 of Experiment 1.

Figure 4



Session 5
Session 2
Responses per Second
Block Position (Trials)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

changed from early to later sessions. Figure 4 shows the within-session pattern of responding from sessions 2 and 5, respectively. In session 2, Group B/ALL showed a substantial decline in responding to the CS between the first and second positions in the train. By session 5 this drop appears to be reduced. A statistical analysis of this pattern did not reveal a significant interaction between block position and session. However, comparing sessions 2 and 5 it is evident from the figure that in session 2, CSs at later positions received a far smaller proportion of the responses directed to the CS in position 1 than was the case in session 5. In other words, the curve for session 5 is flatter than the curve for session 2, which resembles the between-groups pattern for Groups B/1st, B/2nd, ..., B/16th. The reasons for examining this change in pattern over training sessions will become clear to the reader when the results for Group B/All are discussed in Chapter 3.

Discussion

The results from Experiment 1 show that when USs are presented in a closely spaced train and only one US is signaled, the position of the CS-US pairing plays a substantial role in determining whether or not a CS will be conditioned. Trials which were preceded by as few as two closely spaced unsignaled USs were not effective in bringing about conditioned responding. On the other hand, when all USs in the train were signaled by the CS, responding was acquired to CSs at every block position. This pattern of results raises two major questions which the remainder of the thesis explores. First, what is the process by which unsignaled USs occurring immediately prior to the CS-US pairing prevent acquisition of responding to the CS? Second, why does signaling the prior USs by the CS allow the acquisition of responding to the CS throughout the train? The discussion now turns to a consideration of these two questions. The implications of these findings for the theories of conditioning reviewed in the introduction are taken up in the discussion that follows and again in greater detail in the General Discussion of this thesis.

Consider first the results from the single-trial groups in Experiment 1. For the purposes of exposition, the differential acquisition measured across the various temporal positions in the feeding train (when the CS appears only at that position) will be referred to as the "trial location effect". What is the nature of the process by which late trials in the train are prevented from being effective? Consider the following possibilities.

One possible cause of the trial location effect is satiety. As the number of USs prior to the trial increases, subjects ingest more food, and might become relatively more satiated and thus less likely to respond to the CS. Although this account is attractive for its simplicity, it does not square with the fact that Group B/All responded to

CSs at all positions in the train of USs. Satiation due to repeated USs would be expected to affect subjects in this group as well as the others. Nonetheless, satiation prior to the first encounter with the CS could affect acquisition differently than satiation which takes place over the course of massed trials, and the satiation hypothesis therefore needs to be tested directly.

Another way in which preceding USs might interfere with a CS-US trial is through inhibition of conditioning from prior reinforcement. Both Catania (1973) and Williams (1983) have argued that reinforcement generates an inhibitory after-effect capable of interfering with subsequent conditioning. Although they developed the evidence for inhibition due to reinforcement in operant rather than in Pavlovian conditioning it is possible that inhibition underlies the trial location effect in autoshaping.

The satiety and inhibition accounts are based on rather different processes, but they are similar in one sense. These accounts of the trial location effect do not depend on associative processes but rather on unconditional or direct effects of the USs occurring prior to the CS-US pairing. These accounts may be contrasted with another class of explanations, to which we now turn, which look to associative processes in order to explain the trial location effect.

One possible explanation of the trial location effect is based on an associative process that was described in the Introduction, namely blocking of acquisition to the CS due to conditioning of the context by the preceding unsignaled USs (Kamin, 1969; Rescorla and Wagner, 1972). Tomie (1981) and others have provided evidence that contextual blocking can occur in autoshaping (Blanchard and Honig, 1976; Tomie, 1976a, 1976b; Baker and Mackintosh, 1977; Randich and Lolordo, 1979).

A fifth possible account of the trial location effect is offered by scalar expectancy theory. The design adopted in Experiment 1 might have eliminated scalar expectancy theory (SET) as an account of the trial location effect except for the unexpectedly rapid acquisition which was measured in that study (see below). Although scalar expectancy theory is an averaging theory, the averaging is presumed to take place at the time each US is presented (Gibbon and Balsam, 1981). Thus as each US in the train was presented in the first session, the overall expectancy for the US increased. This increase leads in turn to a decrease in the expectancy ratio for the CS, which, according to the theory, will decrease the probability of responding to the CS. It is conceivable, therefore, that the deterioration in the expectancy ratio as the position of the trial is moved further into the block is responsible for the trial location effect. This account is plausible in the light of the extremely rapid acquisition measured in Experiment 1, which indicates that the first trial had a large effect. Hence prior USs might act to disrupt learning which would otherwise result from the trial in a fashion which is consistent with scalar expectancy theory (SET).

There is, however, a problem with this account. The durations of the wait before the train and of the wait in the CS may be used to calculate the expectancy ratio for the CS at any location in the train. If these values are compared with the values reported in several published studies (eg. Gibbon, et al., 1977; Jenkins et al, 1981; Jenkins and Lambos, 1983), the number of subjects that acquired in the B/3rd through B/16th groups of Experiment 1 is expected to be far higher than was found. For example, the value of the expectancy ratio at the 9th position is 10.7:1. Gibbon et al. (1977) report that 100% of subjects exposed to an expectancy ratio of 8:1 or 12:1 acquired conditioned responding. But in Experiment 1, no subject in Group B/9th emitted more than 6 responses to the CS, and all were made in the first two sessions after which responding ceased completely in all subjects. The account offered by SET is therefore, not in accord with the data on the trial location effect.

It is, however, possible to modify SET to accommodate the results on the trial location effect (from the single CS location groups). Although the present statements on SET

(Gibbon and Balsam, 1981) assume that expectancy for the US is the arithmetic average of variable interUS intervals over the experimental context, this assumption could be modified without changing the basic conception of the theory by assuming that recent interUS intervals receive a heavier weighting in overall US expectancy than intervals more distant in time. Another way to express this is to assume that the averaging of variable intervals is exponential rather than linear. As the CS is moved further into the train the number of recent short interUS intervals grows, so exponential averaging (rather than linear) might account for the trial location effect. Killeen (1981) has provided a formal theory based on the concept of an exponentially weighted moving average to account for effects of local averaging.

These four hypothetical accounts of the local context effect (satiety, inhibition, context blocking, and exponential averaging within SET) are considered in further detail in the discussion of Experiments 2 and 3, which provide empirical evaluations of these possibilities.

There remains another possible cause of the trial location effect. Unsignaled USs occurring regularly just prior to the trial might interfere with acquisition to the CS by acting as alternative signals to the trial CS (Egger and Miller, 1963; Jenkins et al., 1981). If so, acquisition to the keylight CS might be blocked (Kamin, 1969). The blocking stimulus would not be the context, as in the Rescorla–Wagner theory, but a prior US serving as a signal of the next US. Support for this notion can be found in the literature. Egger and Miller (1963) showed that USs delivered immediately prior to CS–US pairings (in their "redundant" group) could prevent conditioning that would otherwise result from the pairing (as measured in a group for which the pre-trial USs were delivered at other times during the session, their "simple conditioning" group). Egger and Miller (1963) held that this result was due to the difference in the predictiveness of the intervening stimulus between the redundant and simple conditioning groups. They write "...the first pellet always predicts the delivery, 2 sec. later, of three additional pellets....Thus the intervening stimulus is redundant, even though it is followed by primary reward" (Egger and Miller, 1963, p. 133). Their procedure for establishing the intervening stimulus as a reinforcer was Pavlovian conditioning. Their result implies that the associative strength of the intervening CS was lower in the redundant group because the pre-trial US signaled the post-trial USs, interfering with conditioning. The procedures used in Experiment 1 for the groups that received the pairing at positions other than the front of the train are procedurally analagous to those used in the Egger and Miller (1963) study.

The trial location effect may, therefore, involve competition between the keylight CS and preceding USs acting as signals. This hypothesis is tested directly in Experiments 3 and 4. Discussion of the results from Group B/All is postponed until Chapter 3.

CHAPTER 2

EXPERIMENTS 2 - 4: EXPLORATION OF THE ROLES OF PRE- AND POST-TRIAL USs IN THE TRIAL LOCATION EFFECT AND TESTS OF VARIOUS ACCOUNTS OF THE EFFECT

Experiment 2

Introduction.

In the discussion of the results of Experiment 1, it was mentioned that satiety might provide a simple, nonassociative account of the trial location effect. As more USs precede the trial, subjects might ingest enough grain to become satiated and fail to acquire conditioned responding. Another nonassociative account of the trial location effect considered above was that conditioning to the trial cue might be disrupted by inhibition generated from pre-trial reinforcers.

These two nonassociative accounts of the trial location effect make a similar prediction. If either satiation or inhibition from the USs in the train were interfering with conditioning of the CS, then on the plausible assumption that both satiation and inhibition would increase with the magnitude of reinforcement, a longer pre-trial US would be expected to cause more disruption than one of short duration. Experiment 2 was designed to test this hypothesis directly using a simple design. Two groups were compared using the B/2nd procedure from Experiment 1, where the single daily CS preceded the second US in the train. The groups differed only in the duration of the first US in the train. For one group, the first US in the train (occurring immediately prior to the trial) was made to be 16 seconds in duration. For the other group, the duration was the usual 4 seconds, as in Experiment 1. Thus for this group the duration of the US which preceded the trial was equal to the total duration of the 4 USs which preceded the trial in group B/5th of Experiment 1. If Group B/5th in Experiment 1, which showed very little acquisition, did not acquire because of pre-trial inhibition or satiation, then the group which was given the 16 second US before the trial in the present experiment should also not acquire. If, on the other hand, the duration of the US prior to the trial did not play a role in Experiment 1, then both groups in the current study should show the same level of acquisition as Group B/2nd from Experiment 1.

Method

Subjects. Twenty-four experimentally naive racing homer pigeons were maintained at 80% of their free-feeding weights.

Procedure. Subjects were hopper trained according to the same procedures used in Experiment 1. Following this, subjects were randomly assigned to the two groups used in this experiment.

The design of this experiment is shown in Figure 5.

Group Short B/2nd was treated identically to Group B/2nd in Experiment 1. Group Long B/2nd was also treated identically to Group B/2nd (Experiment 1) except that the first feeding in the train was changed from 4 s to 16 s in duration. All other session parameters and procedures were identical to those used for Group B/2nd in Experiment 1.

The experiment was run in two replications with six subjects per group in each replication. As in Experiment 1, 16 acquisition sessions were given.

Results

Figure 6 shows the development of responding to CS over the 16 sessions of this study. Both groups showed partial acquisition to the CS. A profile analysis of repeated measures revealed a significant main effect of sessions, F(15,6) = 4.39, p < .05, but no significant effect of group (4 second vs 16 second prior feeding) and no group by session interaction[1].

The results for the groups run in this experiment may be compared with those of Group B/5th from Experiment 1. The mean total responses to the CS over the 16 sessions of

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[1] There was in fact a significant difference in the effect of feeder duration between replications for which no explanation can be offered, as two groups of naive subjects were given identical procedures approximately one month apart. It is interesting that the effect of feeder duration was in opposite directions in the two replications. In neither replication taken alone was there a significant effect of feeder duration; therefore data were combined over replications.

Figure 5. The design used in Experiment 2. The amount of food presented before the trial in Group Long B/2nd is equal to the amount received by Group B/5th in Experiment 1.

Group Short B/2nd

Group Long B/2nd

▮ = 10 s CS

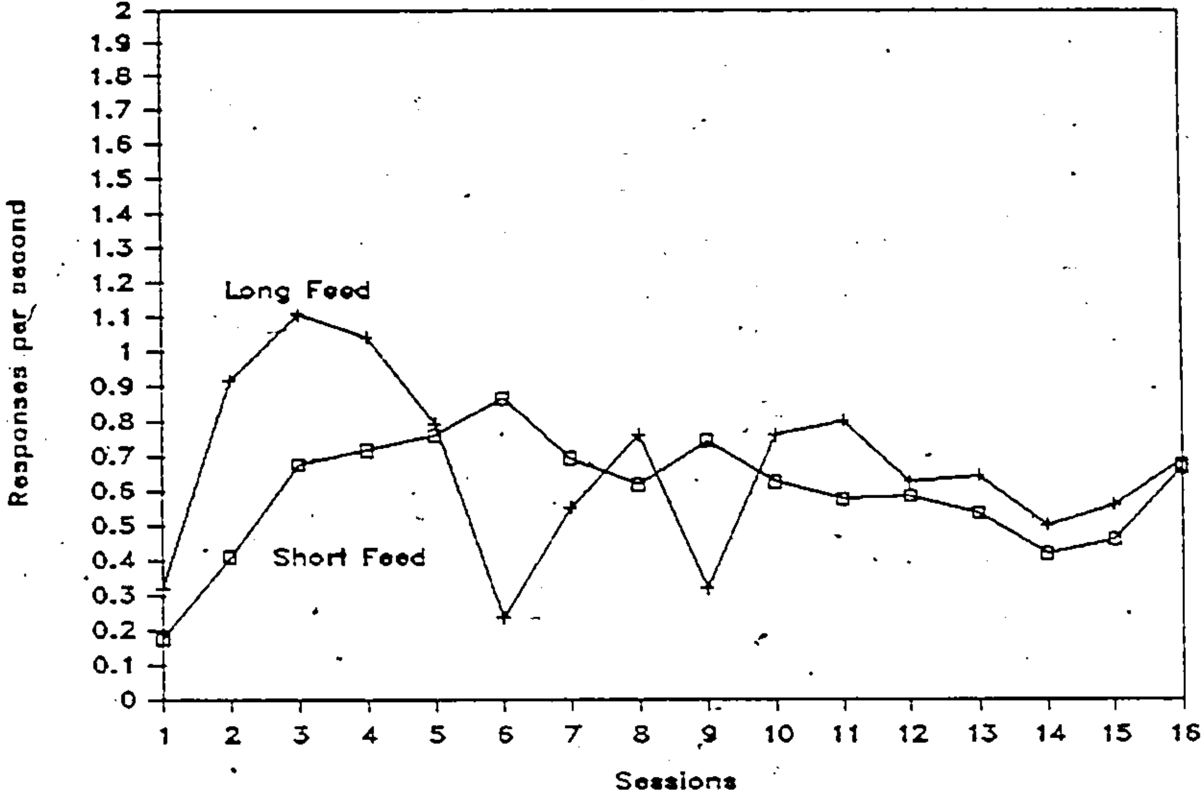
▮▮▮ = 4 s USs

▨ = 16 s US

▬ = no CSs or USs (i.e. time)

Figure 6. Response rate to the CS over sessions, Experiment 2.

Figure 6



Responses per second
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Long Feed
Short Feed
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Sessions

acquisition training for these three groups were: 95.1 for Group Short B/2nd, 106.1 for Group Long B/2nd, and 5.1 for Group B/5th (Experiment 1). The groups differed significantly, $F(2,31) = 3.7$, $p < .05$. A planned comparison of Groups Short B/2nd and Long B/2nd with Group B/5th from Experiment 1 was found to be highly significant, $F(1,31) = 7.31$, $p < .02$.

It is also interesting to compare the two groups from the present study with Group B/2nd from Experiment 1. The mean number of total responses for this group from the acquisition phase was 167.0. Although this figure is higher than that associated with either of the two groups in the current study, the difference between this mean and two means from this experiment is not significant based on an ANOVA ($F(2,31) = .802$).

Discussion

This experiment eliminates the inhibition and satiety hypotheses as accounts of the trial location effect. The duration of the US presented immediately prior to the trial was found not to affect the acquisition of responding to the trial and therefore could not be responsible for the much greater interference with acquisition at the B/5th position as compared with the B/2nd position in Experiment 1. If reinforcement—produced inhibition or satiation were interfering with conditioning to the trial CS at the late block positions, then a larger reinforcement would be expected to result in either more inhibition or more satiety. If this were true, Group Long B/2nd should not have responded to as great a degree as Group Short B/2nd; in fact the mean for Group Long B/2nd was greater than that associated with Group Short B/2nd. Further evidence that the trial location effect does not result from either of these processes is provided by Experiment 3.

Experiment 3

Introduction

In the discussion of Experiment 1 several hypothetical accounts of the trial location effect based on associative processes were suggested. To review, these are the context blocking account, the modified scalar expectancy account, and the account based on blocking from one US serving as a signal for the next in the train. The present experiment was aimed at empirically differentiating among these accounts.

The strategy of Experiment 3 relied on a difference between the first two alternatives and the US signaling account. The context blocking and exponential averaging hypotheses depend entirely on those USs which precede the trial, but the US signaling account depends both on the USs prior to the trial and on the subsequent opportunities to learn that one US predicts another in a short time. Hence if the US signaling account were correct, the manner in which USs are presented following the trial might determine the degree of interference due to the prior USs.

The choice of design for the present experiment was guided by the distinction brought out above. In several conditions the pre-trial contexts were identical, but following the trial the temporal distribution of USs differed for each group. Specifically, the proportion of USs which closely followed one another was varied across groups. If the interference at later locations in the train were due to pre-trial USs being established as signals for a closely following US, then the proportion of USs in the session which follow one another after a short interval should play a role in establishing those USs as signals. According to the US signaling account, the higher the proportion of USs which were followed closely in time by another US, the more they should interfere with the CS-US pairing.

Support for this contention is found in a previously published report. Recall that Egger and Miller (1963) were able to show interference with conditioning of a CS by presenting a US just prior to the CS-US pairing (their "redundant" group). They also included an "informative" group in that study which received the same procedure used for the redundant group except that unsignaled USs were presented randomly during the intertrial intervals. The CS showed significantly more conditioning in the informative group than in the redundant group. According to Egger and Miller, the difference between these two groups is due to the disruption of the signal value of the pre-trial US owing to the unsignaled intertrial USs. The procedure used in Experiment 3 was based on a similar argument.

The procedure for Experiment 3 is shown in Figure 7. For every group the daily procedure was identical up to and including the part of the session where the trial was scheduled. This procedure was the same as that used for Group B/3rd in Experiment 1. The present study provides a direct replication of that procedure, shown at the top of Figure 10, labeled Group B/3 Train. For Group B/3 Random, the remaining USs in the train were presented randomly over the session in runs of one and two USs. The exact distribution used varied each session in accordance with the random event generation routine in the scheduling program. The prediction was that if the temporal distribution of USs following the trial were altered such that one US could not be used to predict that another was soon to follow, subjects would show acquisition of conditioned responding at positions where it otherwise would not emerge. Three other groups were included. For Group B/3 Triplet the USs were delivered in closely spaced runs of length three, separated by variable durations. For this group, two-thirds of the USs were closely followed by another US. Group B/3 Split Train was included to control for the difference in the immediate post-trial context of the US between Groups B/3 Train and B/3 Random. For this group, the remainder of the train was presented intact after a wait of about 8 minutes. Fourteen

Figure 7. The design used in Experiment 3. The procedure for each group is identical up to and including the time of the trial. Groups differ in the number and temporal distribution of USs following the trial.

Group B/3 Train

Group B/3 Random

Group B/3 Split Train

Group B/3 Triplet

Group B/3 Only

▯ = 10 s CS

▯▯▯ = 4 s USs

▬ = no CSs or USs (i.e. time)

of the 16 USs in the train were followed closely in time by another US. If the trial location effect were caused by USs acting as blocking stimuli, then this group would be expected to show similar acquisition performance to Group B/3 Train. Finally, Group B/3 Only received only the first three USs in the train and no other USs in the session. The purpose of this group was to assess the effects of three prior closely spaced USs on conditioning in the absence of other USs in the session.

Method

Subjects. Sixty experimentally naive adult racing homer pigeons were used. They were maintained at 80% of their *ad libitum* weights.

Procedure. There were five groups of n=12 subjects each used in this experiment. Group B/3 Train was a replication of Group B/3rd in Experiment 1. The remaining four differed from Group B/3 Train only with respect to the number and temporal distribution of USs following the trial. For all the other Groups, there was a wait (no CSs or USs) of at least 188.5 s which began immediately following the trial. This time period corresponds to the time that would have passed if the remainder of the train had been scheduled as it had been for Group B/3 Train.

After this wait, the groups received the following treatments. B/3 Random differed from Group B/3 Train in that the remaining 13 USs in the train were distributed in runs of length one or two USs over the last 880 seconds of the session with irregular time intervals separating the runs (see Figure 7). When USs were delivered in pairs they were separated by 10.5 seconds, as they would have been in the train. Between runs, there was a minimum 43.5 s and a mean of 79.7 s. Three runs of length 2 and seven of length 1 were given in each session.

Group B/3 Triplet received a procedure similar to Group B/3 Random except that the remaining USs always occurred in runs of three. There were four runs of length three with a mean separation of 172.5 s. As with Group B/3rd Random, the initiation of the runs over the last 880 seconds of the session occurred at random times except for the restrictions imposed by the 43.5 s minimum wait between runs.

The fourth group in this study is Group B/3 Split Train. In this condition, the remaining 13 USs in the train (which followed the trial immediately for Group B/3rd-Train) were instead presented in a train after a delay of 535 seconds. The USs occurred with 10.5 s separation. Hence the train was split into two parts of unequal length, the first part three USs long and the second part 13 USs long.

The fifth and last group is Group B/3 Only. For this group, the remaining USs in the train were not delivered, and a 1,068.5 s wait followed the trial. The session ended after this wait was over.

Sixteen sessions of these procedures were run for each group.

Results

Table 2 shows the percentage of subjects in each group that acquired and the acquisition scores for subjects that did acquire. The number of subjects that acquired among groups differed significantly on a Chi-Squared test, $X^2(4) = 29.9$, $p < .001$. Examination of Table 2 indicates that Group B/3 Random acquired fully, Groups B/3 Only and B/3 Triplet showed partial acquisition, and Groups B/3 Train and B/3 Split Block showed very marginal acquisition (1 out of 12 subjects in each case). As in Experiment 1, the acquisition scores for those subjects that did acquire did not differ significantly.

Figure 8 shows response rate to the CS over sessions for all groups. Response rates are in general accord with acquisition frequencies. The data in Figure 8 were analyzed via profile analysis. The analysis revealed a significant main effect of sessions, $F(15,41) = 2.98$, $p < .01$, a significant effect of treatment, $F(4,55) = 3.29$, $p < .02$, and a marginally significant treatment by session interaction $F(60,158) = 1.50$, $p < .05$. A comparison contrasting Groups B/3 Train and B/3 Split Train with the other groups (collapsing over sessions) revealed that the difference between these sets of groups was highly significant, $F(1,55) = 12.35$, $p < .001$. This comparison supports the hypothesis

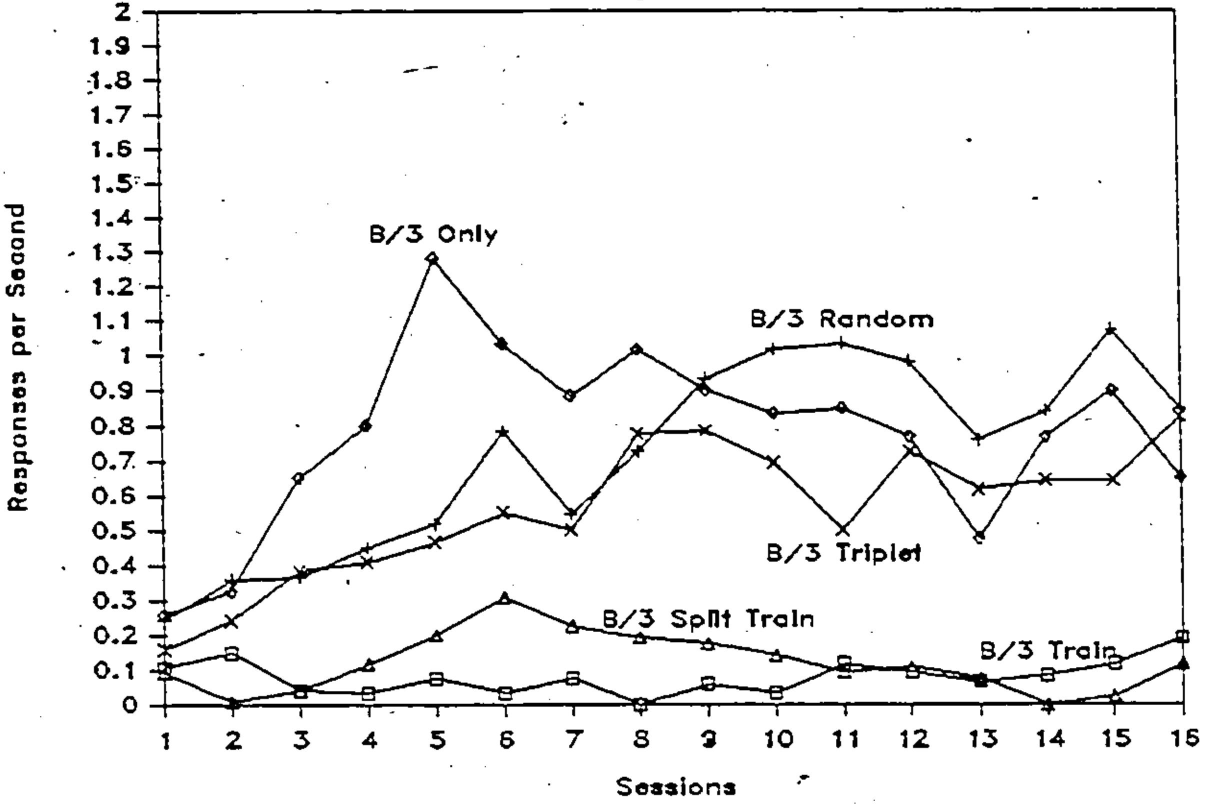
Table 2

Acquisition scores from Experiment 3

Group	% Subjects Acquired	Median Score
B/3 Train	8.3	2
B/3 Split Train	8.3	2
B/3 Random	100.0	6
B/3 Only	66.7	3
B/3 Triplet	50.0	2.5

Figure *8*. Response rate to the CS over sessions, Experiment 3.

Figure 8


Responses per Second
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
B/3 Only
B/3 Random
B/3 Triplet
B/3 Split Train
B/3 Train
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Sessions

that the trial location effect depends on the extent to which the occurrence of one US predicts that another US will follow closely in time. There were no significant differences among Groups B/3 Random, B/3 Only, and B/3 Triplet.

Discussion

These results support the US to US signaling account of the trial location effect. The percentage of subjects that acquired in each group was a function of the proportion of USs following the trial that were followed closely in time by another US. When this proportion was reduced sufficiently, the interference seen in Groups B/3 Train and B/3 Split Train was significantly reduced. The fact that conditioning of the CS at position 3 could be brought about by manipulating the post-trial distribution of USs suggests that competition from USs acting as signals is the cause of the trial location effect. At the same time, these results show the inadequacy of any account of the effect which looks solely to the pre-trial context. Such accounts include the exponential averaging modification to scalar expectancy theory discussed above, the satiety account, and the inhibition account. Moreover, the fact that the pre-trial context was the same for all groups eliminates a context blocking interpretation. If conditioning of the context were interfering with the acquisition of conditioned responding to the CS, such contextual conditioning would be expected to be the same prior to the trial for all of the five groups.

However the groups differed in performance based on the temporal distribution of USs following the trial. These results establish that the source of the trial location effect is competition for associative strength from unconditioned stimuli occurring prior to the CS–US pairing.

The fact that unsignaled USs can act as signals for each other in the autoshaping paradigm is a novel finding. In the general discussion of these experiments, the role that this type of US signaling could play in a variety of other, more common conditioning preparations is considered. Presently, the results of this experiment raise another question.

Recall that in Experiment 1, the group that received the CS–US pairing at the second position in the train (Group B/2nd) showed over 60% acquisition. Considering that Group B/3rd showed almost no responding to the CS, why did the B/2nd subjects show so much acquisition? If two prior closely spaced USs are sufficient to interfere with conditioning (when all the USs are closely spaced), why is one US not enough? One possible answer is simply that two USs provide a better signal than one US, even after the USs are established as signals. In fact, it is possible that the massing of US presentations experienced by subjects during tray training plays a role in the interference subsequently measured when the CS is introduced. If so, two closely spaced USs could serve as a cue that USs are currently massed, while a single US such as the one presented at the start of the session might not.

Another tentative answer is that responding to the CS at position 2 develops before subjects learn that when one US occurs, another will soon follow, but by position 3, (after just two USs) the US has become a signal that another US will follow. In any case, if responding to the CS at position 2 is acquired before subjects discriminate that USs are closely spaced, such responding might persist even if subjects subsequently learn that USs signal one another. In other words, it is suggested that US to US signaling can interfere with the acquisition, but not the maintenance, of conditioned responding.

The preceding account needs explication. Assume that different predictors of the US compete for predictive strength, and further that the first source which acquires such strength will block out other sources. This is akin to the competition assumption of the Rescorla-Wagner theory (Rescorla and Wagner, 1972). In the present series of experiments, the two sources which compete are the trial CS and the previous US. The US is established as a predictor as a result of the repetition of USs in the train or during hopper training, but because USs also occur singly (at the start of the session), at least two USs are necessary to signal that subsequent USs follow in a short time. The trial CS also predicts the next US. According to this view, the question of importance is which is established as a signal first, the CS or the preceding US. The answer is that for the arrangement used in Experiment 1, it depends on the location of the CS in the block. The further into the train that the CS is placed, the more likely the subject will discriminate that USs are massed (and therefore each US predicts the next US) before the subject learns that the CS predicts the US. Given the data from Experiment 1 it appears that position 2 is a half way point in this competition for associative strength, and hence groups receiving this treatment not only show partial acquisition but high intersubject variability.

This view has several implications. One of these is that the development of US to US signaling must either be rapid, being complete in a single exposure to the train of USs, or be established during hopper training. This is not unusual, however. In other autoshaping studies, acquisition has been demonstrated to be complete in less than six trials (eg. Jenkins et al., 1981). It is therefore, not unlikely that the USs could be established as signals before or some time during the first session. Another implication of the view that the CS competes for conditioning with the USs in the train is that if learning about the temporal distribution of USs in the session, including the single US delivered at the start of the session, is established before the subject has experience with the CS, acquisition to the CS should be blocked, even at the 2nd position, where in original training acquisition would be moderate. This implication was tested in Experiment 4.

Experiment 4

Introduction

The preceding discussion implies that if the CS-US pairing appears at an unfavorable position in the train at the start of conditioning, so that the US to US signaling is established before the CS becomes a signal, then shifting the location of the CS so that it precedes the 2nd US in the train should have no effect. On the other hand, shifting the position of the CS to the first position should bring about a strong acquisition since the blocking stimulus (the first US in the train) will not yet have occurred. This implication was tested in Experiment 4.

Method

Subjects. The 70 subjects were the same as those used in the single location groups in Experiment 1 (B/1st, B/2nd, ..., B/16th but not B/All). Subjects were maintained at 80% of their *ad libitum* weights.

Procedure. Experiment 4 is a follow up study to Experiment 1, and was actually run immediately following that study. However, because the implications of these data were not fully understood until Experiment 3 was completed, these results are presented in a different order than the order in which the data were collected.

The position of the CS in the train of USs was changed for some of the groups in Experiment 1 but not for others. Groups B/1st and B/2nd continued to receive the same treatment as in Experiment 1, but all other groups received a new treatment. Each of the other groups except Group B/All was divided at random into two groups of five pigeons each, and one of these groups was now given the same treatment being given to Group B/1st; the other received the treatment given to Group B/2nd.

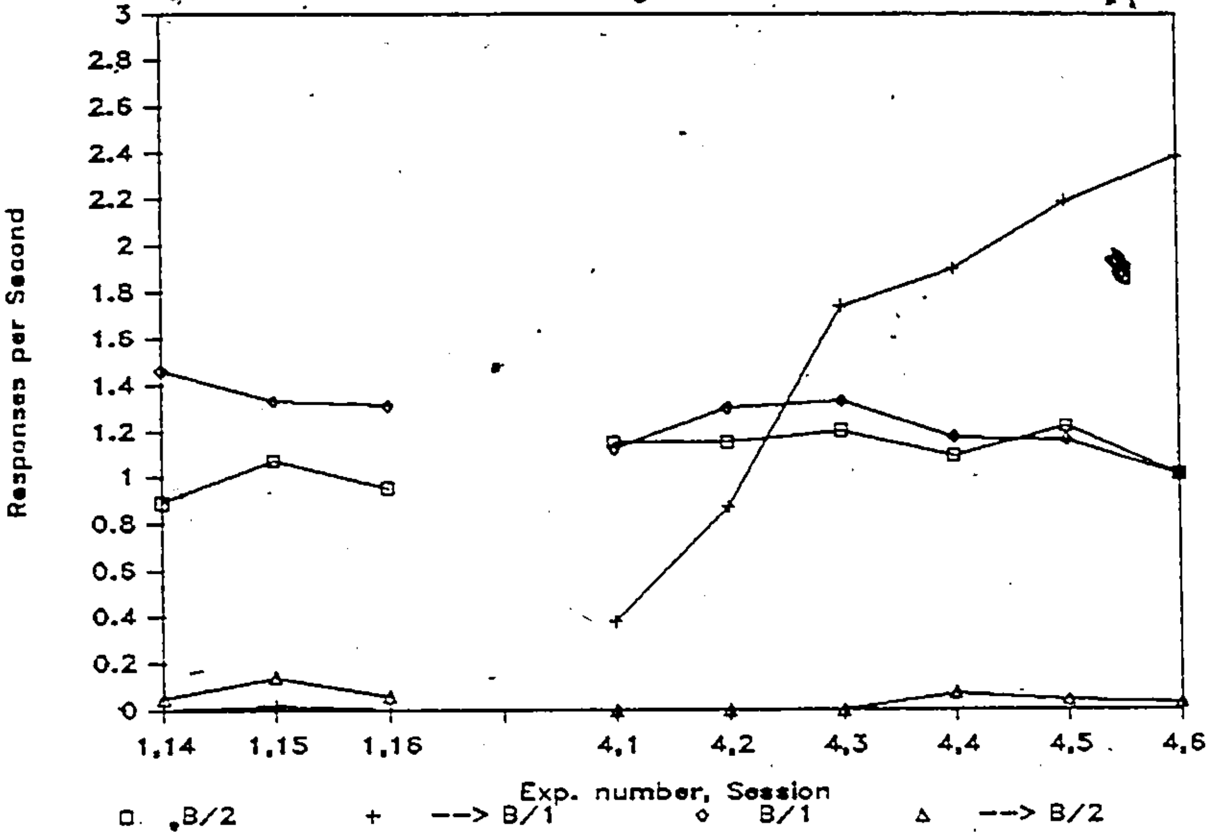
Six sessions of these treatments were run. The dependent variables of interest again were acquisition speed, rate of responding to the CS over sessions, and total number of responses emitted during each phase.

Results

The results from Experiment 4 are presented in Figure 9. As can be seen in this figure, the shift to the B/1st procedure brought about rapid development of responding to the CS, replicating the effect of this procedure from Experiment 1. A statistical comparison of responding over the first 6 sessions between the group shifted to the B/1st procedure in the present study and Group B/1st from Experiment 1 revealed a significant main effect of sessions, $F(5,14) = 12.79$, $p < .001$, but no significant difference between groups, $F(1,18) = 0.66$, and no group by sessions interaction, $F(5,14) = 1.33$, $p < .4$. This comparison indicates that the results from the group shifted to the

Figure 9. Response rate to the CS in the last three sessions of Experiment 1 and the six sessions of Experiment 4. The group labeled "—>B/1" is comprised of those subjects from Groups B/3rd, ..., B/16th in Experiment 1 that were subsequently shifted to the B/1st procedure. The group labeled "—>B/2" is comprised of the subjects from Groups B/3rd, ..., B/16th in Experiment 1 that were shifted to the B/2nd procedure. The subjects in Groups B/1 and B/2 were the same subjects from Groups B/1st and B/2nd in Experiment 1 and continued to receive the same treatment as in Experiment 1.

Figure 9


3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Responses per Second
1,14
1,15
1,16
4,1
4,2
4,3
4,4
4,5
4,6
Exp. number, Session
□ B/2
+ --> B/1
◇ B/1
△ --> B/2

B/1st procedure are quite comparable to the group that originally was exposed to this procedure.

Those subjects shifted to the B/2nd procedure did not acquire conditioned responding to the CS, whereas those trained under the B/2nd procedure from the outset (Experiment 1) did acquire. A single feeding prior to the trial can block responding to a CS when there has been previous exposure to the train of USs.

Discussion

The results of Experiment 4, when compared with certain results obtained in Experiment 1, lead to the following summary. When subjects are trained from the outset with the CS in the second position, (i.e., after the first US in the train and before the second), a substantial level of conditioned responding develops (Experiment 1). If, however, they are first trained with the CS presented in a later position in the train, where conditioned responding does not develop, and are subsequently trained with the CS shifted forward to the second position, very little conditioned responding develops. This is what would be expected on the view that US to US signaling can block CS to US signaling. Prior exposure to the train of USs would establish the first US in the train as a signal that subsequent USs will follow in a short time. When the CS is shifted forward in the train to a position in which it would normally condition, the already acquired signaling function of the first US in the train blocks conditioning to the CS.

The group which was shifted to the B/1st procedure in the present experiment responded indistinguishably from Group B/1st in Experment 1, which received that procedure from the outset of training. There was, therefore, no evidence for latent acquisition to the CS during training in a late position. Rather, it appears that the CS was not conditioned until its location was changed so that it signaled the very first US in the train.

The equivalence in the rates of conditioning between the shifted group and the group originally exposed to the B/1st procedure has another implication which needs to be considered. The blocking account assigns the loss of conditionability to exposure to the train of USs prior to the receipt of the CS in a normally conditionable location. The subjects in Experiment 4 were, however, also exposed to the CS in a position where it does not condition prior to their exposure to the CS in a conditionable position. Another possible account of the results from Experiment 4 is that exposure to the CS in a position where it does not condition might degrade the CS (the animal might learn to ignore the CS) and this, rather than blocking from US to US signaling, might be responsible for the subsequent failure to condition when the CS is shifted forward. Against this account is the observation that if the CS is shifted forward so that it precedes the first US in the train, it conditions as rapidly as it does when it is presented in that position from the outset of training. The CS does not, therefore, appear to be degraded by being exposed in an unfavorable location. The results of the present experiment lend further support to an explanation of the trial location effect in terms of blocking by US to US signaling.

The discussion now turns to the analysis of the B/All group in Experiment 1, about which very little has been said to this point.

CHAPTER 3

EXPERIMENTS 5 THROUGH 7:

A TEST OF THE HYPOTHESIS THAT RESPONDING TO THE CS LATE IN THE TRAIN WHEN ALL USs ARE SIGNALED IS SOLELY THE RESULT OF GENERALIZATION FROM EARLY TRIALS IN THE TRAIN

Experiment 5

Introduction

The trial location effect is interpreted as the result of blocking of Pavlovian conditioning by pre-trial USs which themselves become signals for the trial US. The results of Experiment 1 showed, however, that blocking is prevented when all of the USs in the train are signaled by the CS. Why does signaling all the USs in the train attenuate blocking from US to US signaling?

Examination of the change, over sessions, in the pattern of within-session responding in Group B/All in Experiment 1 (see Figure 4, p. 30) suggests that responding in this group appeared first to CSs early in the train and subsequently to all the CSs in the train. This pattern suggests at least two hypotheses for the origin of responding to the later trials. First, this responding may have appeared as a result of generalization from early to later positions of the CS. In other words, the reason that subjects responded to the CS when it was presented at later positions was that it resembled (identical except for position) the CS which was conditioned at the front of the train. Second, conditioning of the CSs at the front of the train may have made possible independent conditioning of the CSs presented late in the train. If so, a component of generalization might be involved, but might not be the sole cause of responding to CSs later in the train.

How might the conditioning of CSs early in the train of USs make conditioning later in the train possible? A possibility which has been described previously is that signaling the USs at the front of the train prevents conditioning of the context and therefore eliminates competition for associative strength from the context. Several researchers have found significant effects of signaling intertrial USs with another signal on acquisition performance to the trial CS (Durlach, 1983; Tomie, 1981; Randich and Ross, 1984). The experiment reported by Durlach (1983) is the most relevant to the arrangements used in the present experiments. Durlach (1983) showed that whether a keylight CS came to elicit conditioned responding depended on whether intertrial USs were signaled by a tone. She concluded that the tone prevented the context from becoming a signal, and in so doing prevented the context from interfering with acquisition to the keylight CS. Perhaps the CSs in the train act in the same fashion to prevent context conditioning. Although ~~the~~ evidence from Experiment 4 shows that the trial location effect is not based on context conditioning, the prevention of the trial location effect through signaling might be.

On the other hand, responding to trials late in the train may reflect only the conditioning of a CS earlier in the train. The conditioning of the CS in one position could result in responding to the CS in later positions either through generalization, as mentioned above, or by enabling CS—US pairings late in the train to produce conditioning. Of course, some combination of generalization and conditioning could also be involved.

Experiment 5 attempted to provide empirical support for either the context blocking interpretation or the generalization (possibly plus conditioning) interpretation. Like Experiment 4, Experiment 5 was a follow up study to Experiment 1 and was run concurrently with Experiment 4. The procedure for the B/All group was altered by removing the CS from the 2nd through 15th locations in the train. This should allow the context to become conditioned by the now unsignaled USs between the first and last positions in the train. If the status of the context at the time of the trial played a role in the conditioned responding to the CS at position 16, then responding to the CS at position 16 should be reduced compared with the level maintained when all USs were signaled, reflecting the role of the signal value of the context.

Method

Subjects. The subjects were the 10 pigeons which made up Group B/All in Experiment 1. Subjects were maintained at 80% of their *ad libitum* weights.

Procedure. The procedure used for Group B/All in Experiment 1 was changed by removing the CS from the 2nd through 15th positions of the train of USs so that only the first and last USs in the train were signaled by the CS. All other parameters were identical. Six sessions of this treatment were run.

Results.

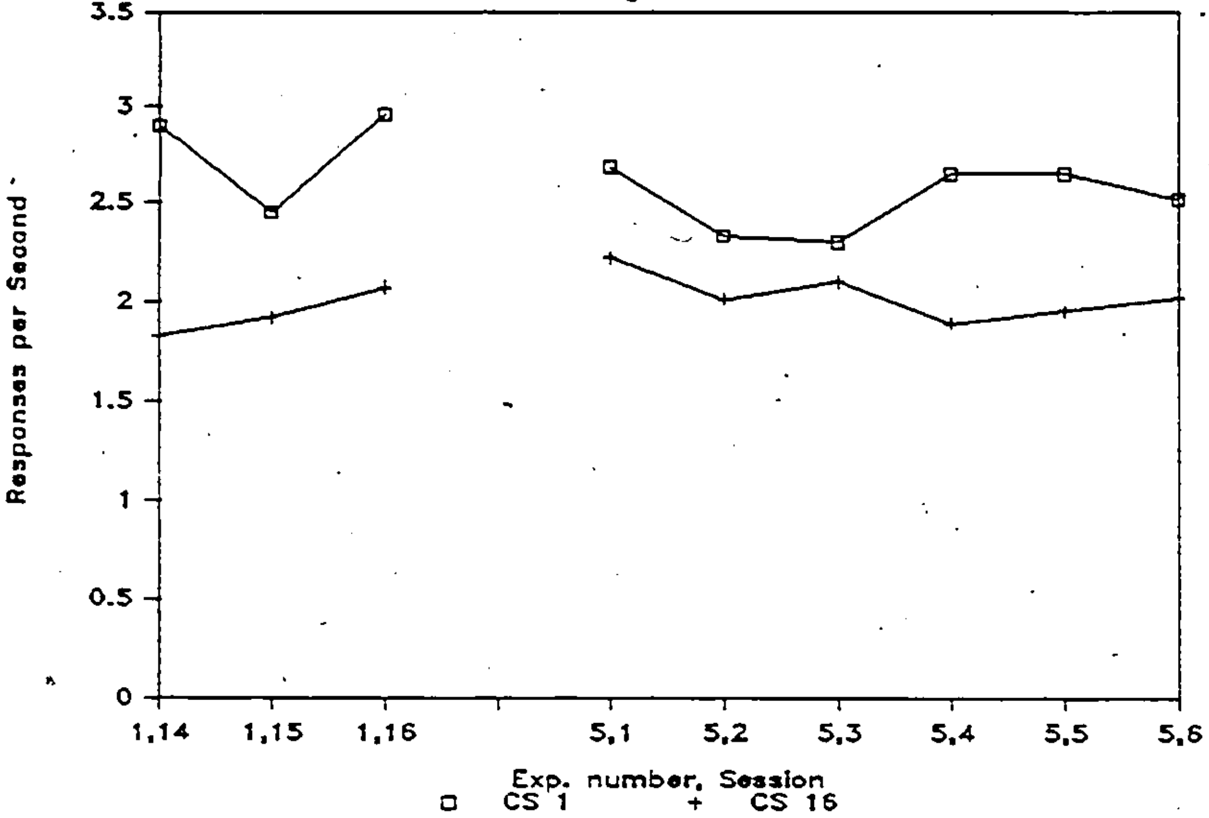
Figure 10 shows responding to the 1st and 16th CSs in the train over the last 3 sessions of Experiment 1 and the 6 sessions of Experiment 5. It is clear from this figure that responding at neither location was affected by the removal of the CS as a signal of the intervening 14 USs in the train. The mean rates to the 1st and 16th CSs on the last session of Experiment 1 were 2.96 responses per s (*SD* = 1.21) and 2.07 responses per s, (*SD* = 1.60) respectively. On the last session of Experiment 5 the means were 2.52 (*SD* = 1.34) and 2.02 (*SD* = 1.37) responses per s. The difference between these two sets of rates does not approach significance.

Discussion

The fact that removing the CS from all but the first and last USs in the train did not affect responding at position 16 is contrary to the hypothesis that responding in

Figure _10_. Rate of responding to the CS at positions 1 and 16 over the last three sessions of Experiment 1 and the six sessions of Experiment 5. The designations along the abscissa are of the format "Experiment Number, Session". The CS was removed from positions 2 through 15 following session 1,16.

Figure 10


3.5
3
2.5
2
1.5
1
0.5
0
Responses per Second
1,14
1,15
1,16
5,1
5,2
5,3
5,4
5,5
5,6
Exp. number, Session
□ CS 1
+ CS 16

Group B/All throughout the train is due to the prevention of context conditioning. Since the 14 intervening unsignaled USs are expected to have conditioned the context, the prevention of the trial location effect through signaling does not seem to depend on the prevention of context conditioning. This is contrary to the result predicted on the Rescorla-Wagner theory.

Removing the CS from positions 2 to 14 radically changed the proportion of USs which were signaled, and thereby also changed the contingency of the CS with respect to the US. Contingency of US on CS does not seem to play a role in determining the level of maintained responding to a CS once acquisition has taken place.

It is not known, however, what affect this procedure would have on subjects exposed to it from the outset of conditioning. The course of acquisition of responding to the CS might be affected by the intervening unsignaled USs even though they did not affect maintained responding.

These results do support the alternative accounts of responding in Group B/All, namely generalization from CSs at favorable locations or generalization plus conditioning of CSs at later locations enabled by conditioning of the CS in a favorable location. The purpose of Experiment 6 was twofold. First, Experiment 6 provided a test of whether withholding the CS from the positions 2 through 14 in the train would affect subjects differently if it were done from the outset of training. Second, Experiment 6 was conducted to help in determining whether generalization alone accounted for the responding to the CS at position 16 in the B/1st & B/16th procedure.

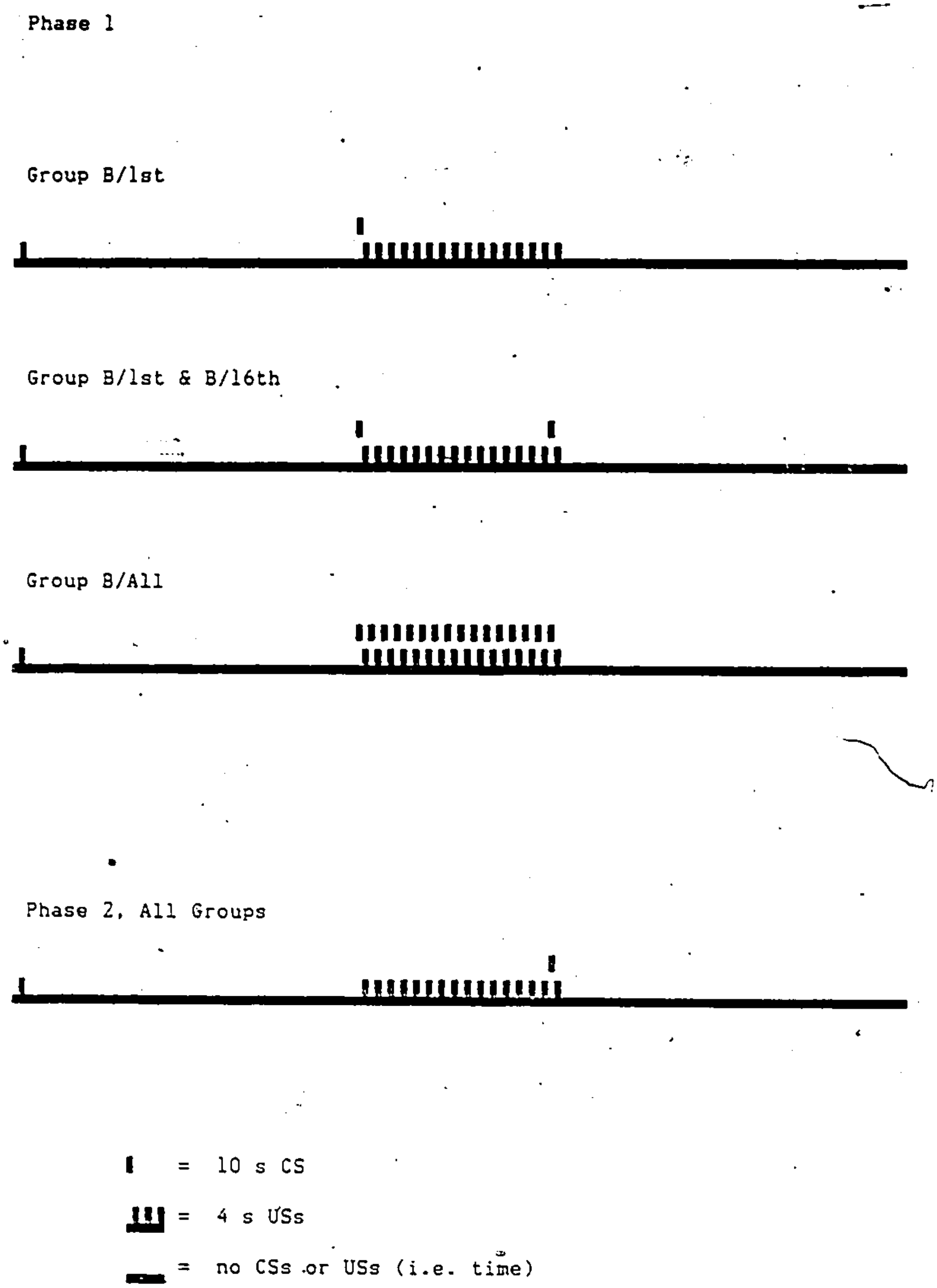
Experiment 6

Introduction

The plan of Experiment 6 is shown in Figure 11. There were three groups in the first phase. One was treated identically to Group B/All in Experiment 1. Another was given the same procedure for Group B/1st & B/16th in Experiment 5, but from the outset of conditioning. A third group was treated identically to Group B/1st in Experiment 1. If generalization across positions from position 1 to position 16 were the sole cause of responding to the CS at position 16 in Group B/All, then there should be no difference in acquisition to the CS at location 16 between Groups B/All and B/1st & B/16th.

The generalization hypothesis was further tested in the second phase. Here, the CS was removed from all but the last US in the train for Groups B/All and B/1st & B/16th, and was shifted to the B/16th location for Group B/1st. If responding to the CSs late in the train <u>in</u> Groups B/All or B/1st & 16th were simply a form of generalization, it would be expected to extinguish without the continued presence of the CS at the earlier position(s). On the other hand, if responding to the CS at location 16 persisted indefinitely

Figure _11_. The design used for Experiment 6.


Phase 1
Group B/1st
Group B/1st & B/16th
Group B/All
Phase 2, All Groups
= 10 s CS
= 4 s USs
= no CSs or USs (i.e. time)

even after the CSs at favorable locations were removed, then it would be necessary to conclude that generalization was not the sole cause of the responding throughout the late positions of the train in Group B/All.

Method

Subjects. Eighteen experimentally naive homer pigeons were maintained at 80% of *ad libitum* weight.

Procedure. Figure 11 shows the procedure for the acquisition and test phases of Experiment 6. There were three groups of 6 pigeons each. Group B/All received the same treatment as Group B/All in Experiment 1. Group B/1st & B/16th differed from Group B/All only in that the second through fifteenth USs in the train were not signaled by the CS. Note that this group received the same procedure used for Group B/1st & B/16th in Experiment 5 except that it was here given from the outset of conditioning. Lastly, Group B/1st was given the same treatment as Group B/1st in Experiment 1, that is only the first US in the train of 16 USs was preceded by the keylight stimulus. The acquisition phase of this study was run for eight sessions. Aside from the location or locations of the CS—US pairing(s) in the train, the session parameters were identical to those used in Experiment 1.

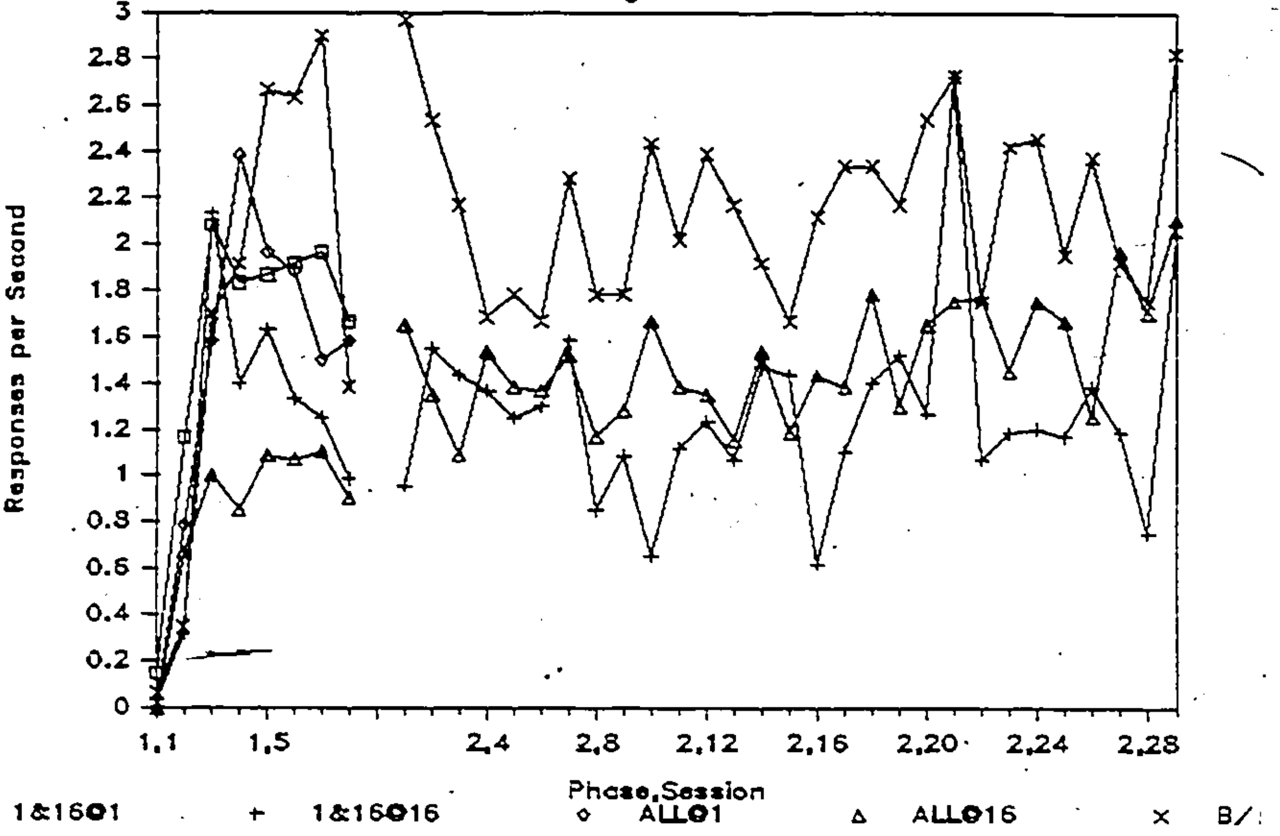
In the second phase, which began on the day following the last session of the acquisition phase, all subjects in each of the three groups from phase 1 were shifted to the procedure used for Group B/16th in Experiment 1. That is, the single CS per session preceded the 16th feeding in the train, and there were no other CSs presented. Twenty-nine sessions of this phase were run.

Results:

Figure 12 shows the results for the 8 acquisition sessions of phase 1 and the 29 sessions of phase 2. The five curves in the first part of the figure show responding to CS 1 for all groups (ie. Group B/1st & 16th, CS 1, Group B/1st & 16th CS 16, etc.). Regarding the acquisition sessions (phase 1), it is clear from this figure that responding to the CS at positions 1 and 16 in each group developed rapidly and was sustained over the course of the eight sessions. Since no responding occurred to the CS in position 16 over the course of the first 8 sessions when it was the only CS (Group B/16th of Experiment 1), the responding measured to the CS which preceded the 16th US in Group B/1st & 16th from the present study indicates that signaling only the first US in the train has a large effect. A statistical comparison of the total responses to the CS at position 16 over the first eight sessions of acquisition was made between Groups B/1st & 16th and B/All from the present study and Group B/16th from Experiment 1. The difference between these two (sets of) groups was significant, F(1,19) = 7.21, $p < .02$. This comparison demonstrates the large effect of signaling the first US in the train with the CS as opposed to leaving it unsignaled.

<u>Figure 12</u>. Response rate to the CS in each phase of Experiment 6. The five curves in the left-hand portion of the Figure show responding to the CS in Group B/All at positions 1 and 16 ("All @ 1" and "All @ 16"), responding to the CS in Group B/1st & 16th at these two positions ("1&16 @ 1" and "1&16 @ 16"), and responding to the CS in Group B/1st. The three curves on the right-hand side of the Figure show responding in phase 2 to the CS for the same three groups. In phase 2, the CS was removed from all positions except position 16.

Figure 12


Responses per Second
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1,1
1,5
2,4
2,8
2,12
2,16
2,20
2,24
2,28
Phase,Session
□ 1&16@1
+ 1&16@16
◇ ALL@1
△ ALL@16
× B/

Comparing Group B/1st & 16th with Group B/All, responding to the CSs at positions 1 and 16 was analyzed by a multivariate profile analysis. There was no significant difference in responding to the CS at positions 1 versus 16 (a within-subjects factor), no main effect of group (ie. treatment), and no significant interaction of group with CS location. Thus Group B/1st & 16th and Group B/All did not differ significantly with respect to responding to the CS.

With regard to phase 2, Figure 12 shows that responding to the CS at position 16 in all 3 groups was sustained for the 29 sessions of this procedure; there was no indication of a decline in responding to the CS over the course of these sessions. Nor was there a significant difference among the three groups (now treated identically) in rate of responding to the CS.

Discussion

The results from both phases of Experiment 6 provide information on how signaling an early US prevents the trial location effect. The important result from phase 1 is that acquisition of conditioned responding to the CS which signaled the 16th US in the train depended only on the first US in the train also being signaled. It made no difference whether the USs at positions 2 through 14 were signaled, even though the percentage of USs which were signaled was radically different across the three groups. This result shows that neither protection from context conditioning nor

CS–US contingency can explain the disappearance of the trial location effect when all the USs in the train are signaled by the CS.

The Phase 2 results demonstrate that once conditioning has occurred to the CS in a favorable location—one at which conditioning would not occur initially— responding continues even though the CS is no longer being presented in the favorable location. The source of responding to CSs late in the train cannot, therefore, be due solely to generalization across locations. If it were, removing the source of that generalization would be expected to result in extinction at the later location, and that did not occur. On the other hand, generalization must play a role because Group B/1st from this experiment responded to the CS at position 16 on the very first session that the CS was presented there. It is clear that both generalization and conditioning at the later locations contribute to the responding to CSs later in the train of USs.

The maintenance of responding when the CS is presented only at position 16 raises several questions. First, is it the case, as seems likely, that the presentation of the US following the CS is necessary to maintain responding? If so, has prior conditioning altered the susceptibility of the CS to classical conditioning; i.e., is the CS–US pairing now capable of bringing about classical conditioning in a position where conditioning would, as we have seen, otherwise be blocked by the signal value of prior USs? Alternatively, the US could be serving as an operant reinforcer of the pecking response even though the response had its origin in generalization from classical conditioning of the CS in a favorable location. In other words, maintenance could be due to a response-reinforcer relation rather than a CS-US relation. If so, the process would conform to superstitious operant conditioning (Skinner, 1948; but see Staddon and Simmelhag, 1971) since the presentation of the reinforcer is not contingent on the response. Experiment 7 was designed to resolve these issues.

Experiment 7

Introduction

The plan of Experiment 7 was as follows. The subjects from Experiment 6 were first placed on extinction by presenting the CS after the last US in the train rather than before it. If the US was responsible for maintaining responding to the CS in phase 2 of Experiment 6, then responding should cease when the CS was unpaired with the US. In the second phase, the CS was again paired with the last US in the train to determine whether reacquisition would occur. As noted previously, the test for reacquisition bears on the question of whether responding to a previously conditioned CS when presented only in position 16 reflects the potentiation of classical conditioning by prior conditioning or alternatively, noncontingent operant reinforcement of generalized responding. If it were the latter, reliable acquisition as a function of pairings would not be expected since opportunities after extinction for strengthening responses in this way might be no greater than when the CS is presented in position 16 without prior conditioning. On the other hand, if prior conditioning prevents blocking by prior USs, thereby making the CS-US pairing in the late position effective for classical conditioning, reliable reaquisition as a function of CS-US pairings would be expected.

Method

Subjects. The same subjects and apparatus used in Experiment 6 were used.

Procedure. There were two phases in Experiment 7. In phase 1, the CS which previously signaled the US at position 16 in the train was placed on extinction by presenting it .5 sec after the 16th and last feeding in the train instead of 10 sec prior to it. At this position it was not followed by a feeding. This procedure was run for 16 sessions. In phase 2, the CS was again presented prior to the last US in the train for 16 sessions.

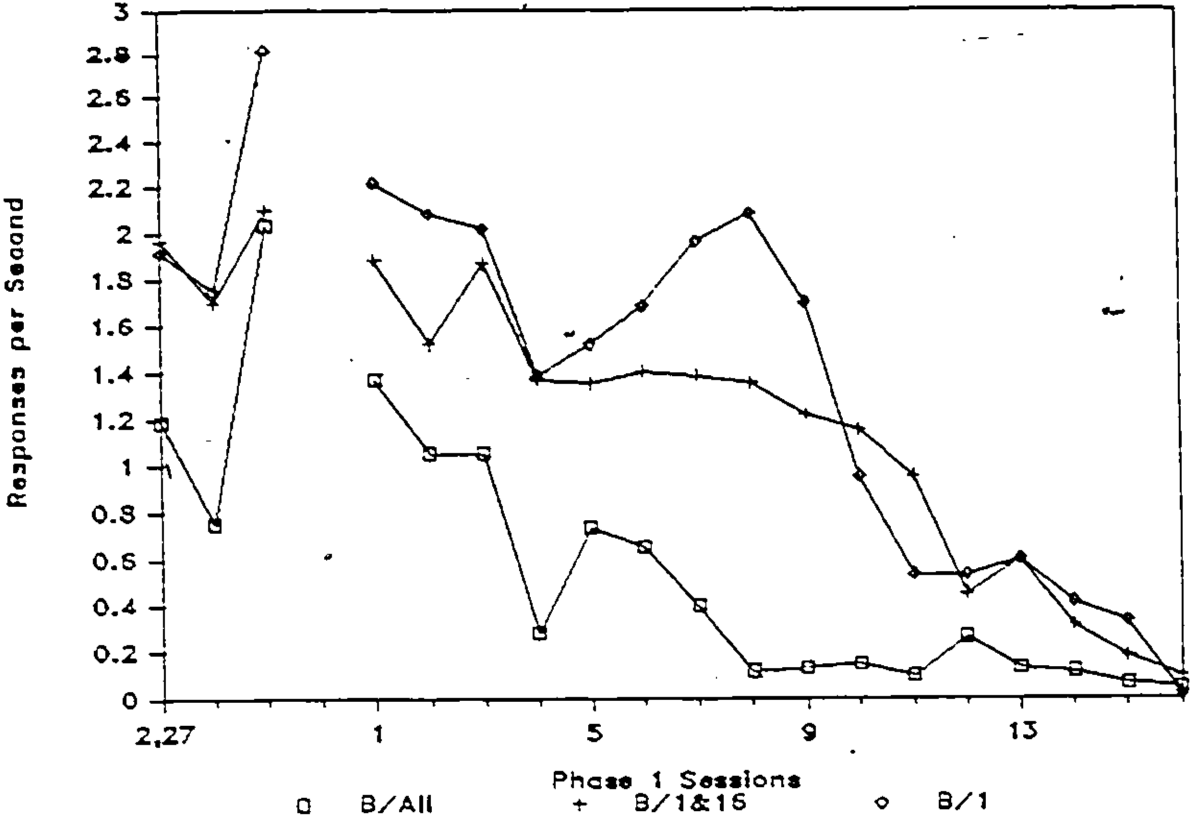
Results

The results from phase 1 of Experiment 7 are shown in Figure 13. Responding declined steadily over these sessions and was eliminated by the last three sessions of this treatment.

The results from the reacquisition test are shown in

Figure 13. Responding to the CS in the last three sessions of Experiment 6, phase 2 (when all subjects received the CS at position 16) and phase 1 of Experiment 7. The CS was no longer reinforced in phase 1 of Experiment 7. Subjects in the three groups used for Experiment 6, phase 1 were treated identically in Experiment 6, phase 2 and in both phases of Experiment 7.

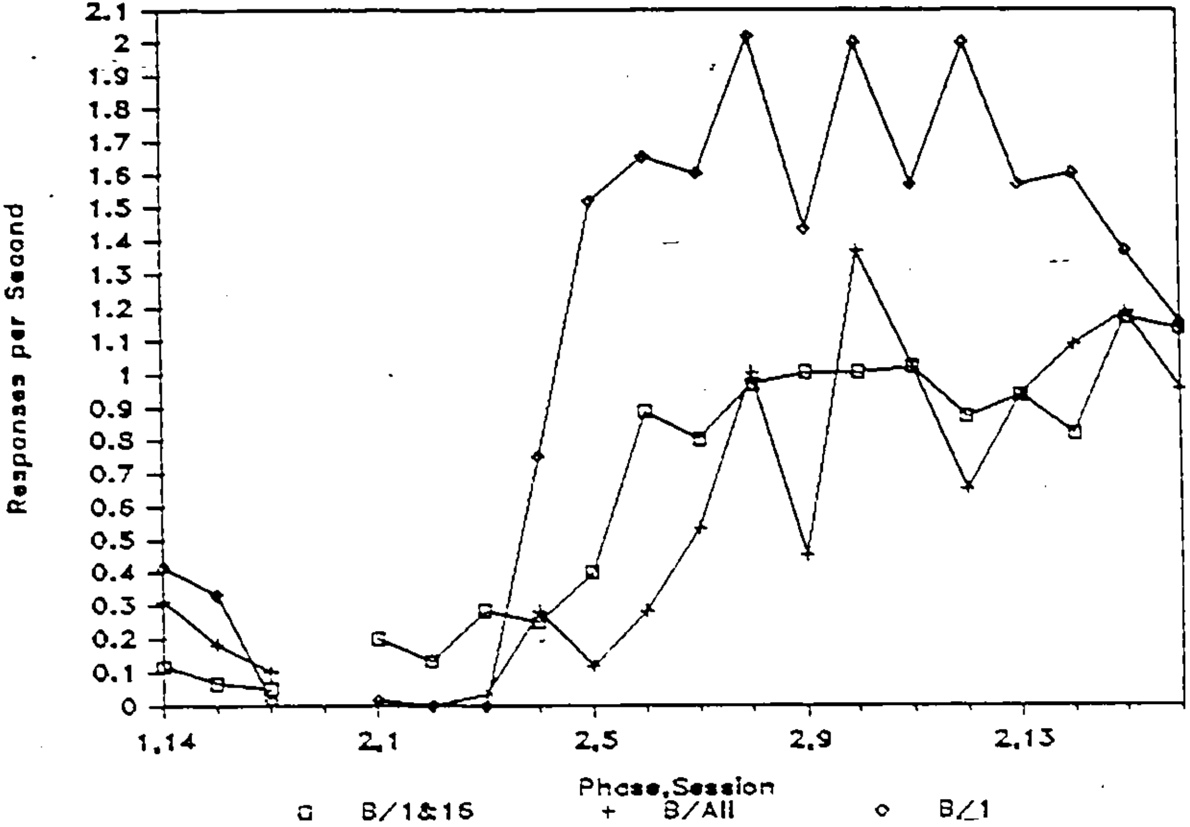
Figure 13



3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Responses per Second
2,27
1
5
9
13
Phase 1 Sessions
□ B/All
+ B/1&16
◇ B/1

Figure 14. Responding to the CS in the last three sessions of phase 1 (extinction) and the 16 sessions of phase 2 (reaquisition), Experiment 7. In phase 2 the CS was once again presented prior to the 16th US in the train (i.e. the B/16th procedure).

Figure 14



Responses per Second
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1,14
2,1
2,5
2,9
2,13
Phase,Session
□ B/1&16
+ B/All
◇ B/∠1

Figure 14. Subjects gradually reacquired conditioned responding to the CS at the B/16th location until such responding reached the level it had attained in the previous treatments. A one way ANOVA on total responses to the CS from this phase revealed no significant differences among the groups. In all groups, the degree of reacquisition was substantial. The mean responses per s for all subjects during the last three sessions of phase 2 of Experiment 6 was 1.58 (SD = 1.44) whereas for the last three sessions of reacquisition the mean was 1.16 (SD = 1.63). The difference between these means indicates that the degree of recovery was less than 100%, but the difference does not approach significance.

Discussion

Since extinction of responding to the CS was complete in 16 sessions, the results from phase 1 make it clear that the US following the keylight stimulus at position 16 was necessary for the maintenance of responding to that CS. The sustained responding to the CS at position 16 measured in phase 2 of Experiment 6 was, therefore, dependent on there being a US following the CS.

Although no acquisition was measured when the CS preceded the US at the last position in the train in original training (Group B/16th, Experiment 1), reliable acquisition in this position did occur following extinction after conditioning at a favorable location. The reacquisition of conditioned responding provides further evidence that the responding to all CSs seen in Group B/All (Experiments 1 and 6) is not due solely to generalization from CSs at favorable locations. If this responding resulted only from generalization across locations in the train, then neither the sustained responding measured in phase 2 of Experiment 6 nor the reaquisition of responding following extinction in phase 2 of Experiment 7 should have occurred.

The reaquisition of conditioned responding further rules out superstitious operant conditioning as a primary cause of this responding as well. Responding to the CS at the end of the extinction sessions and during the first two recovery sessions was not greater than was found in the later positions of the train in Experiment 1. Since noncontingent (i.e. superstitious) reinforcement did not result in acquisition in Experiment 1 for Groups B/3rd, B/4th, etc., there is no reason to suppose that it would do so here. Rather, the reaquisition measured in this experiment indicates that prior conditioning of the CS at a favorable location appears to have altered the conditionability of the CS. Another way to state this is that prior conditioning seems to have prevented, or at least greatly attenuated, blocking from prior USs.

These results raise the question, What changes to a CS take place as a result of conditioning that could prevent the CS-US association from being blocked by US-to US associations? One possibility which has been invoked in explanations of conditioning which might account for the current results is that CS conditionability (or associability) might change as a function of experience with the CS. In the Introduction to this thesis several recent accounts of Pavlovian conditioning were reviewed. There it was noted that certain theories looked to changes in associability to account for Pavlovian conditioning phenomena (Mackintosh, 1975; Pearce and Hall, 1980). If it were possible to understand how the associability of a CS changes following experience with the CS, independently of its associative strength, it might be possible to account for the data from the present experiments through a current theory of Pavlovian conditioning. This task is taken up in the General Discussion which follows.

CHAPTER 4

GENERAL DISCUSSION

The principal results of the present experiments may be summarized as follows.

1. When USs are presented in a closely spaced train (which is preceded and followed by a long wait), and only one of the USs in the train is signaled by a CS, conditioning to the CS falls off sharply as the CS is moved further into the train (Experiment 1).

2. When all the USs in the train are signaled by the CS, however, responding occurs to all CSs within a few sessions (Experiment 1).

3. The interference from the unsignaled USs when only one US is signaled is not due to satiation or inhibition (Experiment 2), nor to competition for signal value from contextual conditioning (Experiment 3), nor can it be explained by modifying SET to make the background expectancy depend on the exponential averaging of past interUS intervals (Experiment 3). Rather, the interference is a form of blocking in which the blocking stimulus is the preceding US or USs in the train which become established as signals for the next US in the train (Experiments 3, 4).

4. Signaling even one of the USs at a favorable location (i.e., the front of the train) enables CSs at all locations to evoke responding (Experiments 5, 6).

5. Responding is maintained to a CS at an unfavorable location even when the CS is no longer presented in a favorable location (Experiment 6).

6. Following conditioning at a favorable location, the CS can be extinguished and subsequently reconditioned if placed at an otherwise unfavorable location where acquisition without previous conditioning does not occur (Experiment 7).

Two questions raised by the results reviewed above are discussed. First, do any of the current models of Pavlovian conditioning explain these results? Second, what role might blocking by the unconditioned stimulus play in conventional conditioning arrangements?

Application of a Current Model to the Present Data

In the Introduction to this thesis, several formal models of Pavlovian conditioning were reviewed and the distinction between single and dual process models was emphasized. Single process models such as the Rescorla-Wagner theory stipulate that conditioning involves changes in the associative strength of a stimulus as a result of pairings with another stimulus, the US. This may be contrasted with dual process theories such as Mackintosh's (1975) in which CS—US pairings lead not only to changes in associative strength but to changes in the associability or conditionability of the CS. The present data on the prevention of blocking by prior conditioning require a view of conditioning as resulting in a long lasting change in the associability of the conditioned stimulus. I will examine the question of whether the present data on the change in associability due to conditioning are consistent with Mackintosh's (1975) dual process conditioning, which is the best developed dual process theory at present.

According to Mackintosh's (1975) theory, the salience of a CS, which in part determines whether it will be conditioned, is not a fixed property of the CS but is a variable quantity which changes as a result of conditioning trials. Mackintosh writes "This idea is formally equivalent to one of the main tenets of two stage, attentional theories of learning, namely, the assumption that the probability of attending to a stimulus determines the probability of learning about that stimulus and may itself change with experience." (Mackintosh, 1975, p. 294).

According to Mackintosh, the associative strength, V_{cs}, changes on a conditioning trial according to the following formula (Mackintosh, 1975, equation 2):

$$\Delta V_{cs} = \theta \alpha (\lambda - V_{cs})$$

where λ is the maximum associative strength available from the US, θ is a learning rate parameter, and α represents the salience or conditionability of the CS. (The equation is similar to the one given in the Rescorla-Wagner theory, except that where V_{cs} appears in Mackintosh's equation the total V, based on all stimuli with signal value, not just the CS, appears in the Rescorla-Wagner theory.) In Mackintosh's theory the salience of a CS changes in a positive or negative direction on conditioning trials according to the following equations (Mackintosh, 1975, equations 4 and 5):

$$\Delta\alpha_{cs} \text{ is positive when } \left|\lambda - V_{cs}\right| < \left|\lambda - V_x\right|$$

and

$$\Delta\alpha_{cs} \text{ is negative when } \left|\lambda - V_{cs}\right| \geq \left|\lambda - V_x\right|$$

where V_x is the associative strength of all stimuli other than the CS present on that trial. These equations state that the associability of a CS increases on a conditioning trial whenever the CS has a higher associative level than all other CSs also presented on the same trial, and that the associability of a CS decreases whenever it is presented in conjunction with other CSs which have a higher (or equal) total associative strength. Thus when two unequally conditioned CSs are presented in a compound, the more fully conditioned CS will undergo an increase in associability and the less fully conditioned CS will undergo a decrease in associability.

It is of interest to examine the ability of Mackintosh's theory to account for the most important results from the present experiments, namely the trial location effect and its prevention through signaling USs at the front of the train, the failure to acquire following a shift from a late position to B/2nd as contrasted with acquisition when shifted to B/1st, the maintenance of responding which occurs when the CS is shifted forward to a late location, and the reacquisition of responding which occurs following extinction.

1. In Mackintosh's theory, the trial location effect may be understood as a rapid decrease in alpha for the CS when it is presented late in the train (position 3 or later) which prevents conditioning to the CS. This would occur because each US is predicted by a prior US, whereas only one of the USs is predicted by the CS. V_{us} will therefore be greater than V_{cs} when the procedure allows the acquisition of US to US signaling before CS to US signaling is acquired. As a result, alpha for the CS will decrease. As discussed above, this account requires the assumption that US to US signaling is acquired either during or before the first conditioning session (during hopper training). The prevention of blocking through signaling all the USs in the train is due to a rapid increase in alpha for the CS due to conditioning in a favorable location, which leads to independent conditioning of CSs at late positions in the train as well as to generalization of responding across locations.

2. The difference in acquisition seen when the CS was moved to position B/1st as opposed to B/2nd is, on

Mackintosh's theory, due to an increase in alpha for the CS when it is shifted to B/1st but not to B/2nd. When shifted to B/2nd, the second US in the train is already better predicted by the first US so alpha for the CS remains low and the CS does not condition. When shifted to B/1st, on the other hand, the CS is the best predictor of the first US in the train, and so undergoes a rapid increase in alpha, leading to conditioning. A problem with this interpretation is that if the alpha level of the CS at the later locations was reduced because the prior USs were conditioned first, acquisition at position 1 following the shift should be slower than original acquisition at the B/1st position. Acquisition was not significantly slower in the shifted group than in the group trained at the B/1st position from the outset, although there was a difference in the predicted direction. Since the magnitude of the expected effect depends on unspecified parameters of the theory, the failure to find a significant effect is not decisive evidence against the theory.

3. The maintenance of responding when the CS is shifted forward, to a late position in the train, can be explained on Mackintosh's theory as follows. At the time of the shift, V_{cs} and alpha for the CS will be at high values resulting from conditioning at an early location. If V_{cs} and V_{us} are each conditioned to asymptote before the shift, V_{cs} will equal V_{us} at the outset. Under this condition, or if

V_{cs} is less than V_{us} due to the greater number of US-US pairings, equation 5 states that alpha for the CS will decrease. Mackintosh's discussion leaves open the question of whether performance depends on V_{cs} and alpha or only on V_{cs}. In order to accommodate the present results, however, in which responding to the CS in a late position continues, it appears necessary to assume that performance does not depend on alpha since, as has been shown, the theory implies a decrease in alpha for the CS when it is presented late in the train. There is no reason, according to the theory, for V_{cs} to decrease when the CS is shifted even if alpha for the CS is substantially reduced, and responding is therefore expected to continue.

4. Reconditioning in the late (normally blocked) position following extinction can be accounted for only if it is assumed that alpha for the CS is restored to a high value as the result of extinction. Mackintosh does not discuss the application of his theory to extinction, except to state that it is assumed that on nonreinforced trials the value of lambda is either zero or some negative number. Let us assume that the value is zero, as it is assumed with the Rescorla-Wagner theory. Then the rules for changing alpha stipulate that alpha for the CS will decrease only if $\left| 0 - V_{cs} \right| \geq \left| 0 - V_x \right|$, where X is the continued presentation of the background. Since the CS on its first nonreinforced presentation will have a higher value than the background,

the quantity on the left side of the inequality will be greater than that on the right. Alpha for the CS should therefore decrease. Thus based on Mackintosh's equations, in extinction the alpha level of a CS should decrease until alpha for the CS becomes less than the value of alpha for the background. This appears to be problematic for the application of Mackintosh's theory to the reacquisition in a late position after extinction, but another interpretation of the extinction procedure employed in Experiment 7 is possible. Recall that in that study, extinction was achieved by moving the position of the CS so that it immediately followed the last US in the train. It is possible, therefore, to consider all USs in the train to be reinforced trials (A+) except the last US in the train, which might be considered a nonreinforced compound consisting of the prior US and the CS. In conventional notation, A+ trials preceded AB– presentations. According to Mackintosh's theory, alternating A+ trials with AB– presentations would establish a high alpha level for the added stimulus, B. Mackintosh writes "If A alone signals reinforcement and AB signals nonreinforcement, then α_B will tend to increase rather than decrease, since B must be a better predictor of nonreinforcement than A." (p. 289). Thus, the conditions for extinction in Experiment 7 might result in an increase in the associability of the CS. This increase in associability would account, in theory, for the reacquisition of conditioned responding when the CS was once again moved to position 16.

There are several implications of this interpretation of Mackintosh's theory. The first is that if the CS were extinguished well after the last US in the train rather than immediately after the last US, alpha for the CS would be expected to decline as a result of extinction trials and reacquisition in a late position would not be expected. A second implication is that if, prior to original exposure to the B/16th procedure for a group of subjects, the CS were presented following the train as it was in the first phase of Experiment 7, original acquisition at the B/16th position would be expected. This is for the same reason that reacquisition following extinction would be expected. Unfortunately, the data needed to examine these predictions have not been collected.

Mackintosh's (1975) theory is able to account for the major results from the experiments reported in this thesis. The application of Mackintosh's theory to the present data has been post hoc, however, and further empirical tests such as those suggested above are needed to determine the adequacy of the theory for the set of phenomena associated with the trial location effect. Whatever the goodness of fit of Mackintosh's theory to these phenomena, it remains evident that some form of dual process theory of conditioning is required by the demonstration of long lasting changes in associability due to conditioning.

The discussion now turns to the second of the two questions raised above, namely how might blocking from US to US signaling play a role in ~~conventional~~ conditioning arrangements.

US to US Signaling and Other Conditioning Phenomena

The experiments reported in this thesis demonstrate that USs can function as powerful blocking stimuli in autoshaping. Little attention has previously been paid to the US as a potential blocking stimulus because the unconditioned stimulus is normally viewed as the to-be-predicted event in classical conditioning rather than as a signaling, or predictive, stimulus. The present demonstration that US signaling can block conditioning to a CS raises the question of whether US signaling might be involved in, or even be the major cause of, certain other effects in classical conditioning; in particular, the effects of trial spacing and of preexposure to the US on subsequent conditioning.

Before considering the relation of US to US signaling with these conditioning phenomena, however, a brief digression is necessary. Although it is of interest to consider the possible involvement of US to US signaling in certain phenomena of classical conditioning it must be recognized that the present experiments on US to US signaling involve a number of special conditions. It is possible that these special conditions are necessary for US to US signaling to occur. If so, the applicability of US to US signaling would be limited. These conditions are summarized below.

The procedures employed in the present experiments differ from those employed in more conventional Pavlovian conditioning arrangements. There are at least five properties of the procedures used in most of the experiments reported here that may be considered special conditions. First, the 10.5 s interval between USs in the train is shorter than the interval used in most autoshaping procedures, which typically vary from 30 seconds to several minutes (eg. Gibbon et al., 1977; Jenkins et al., 1981; but not always: see Figure 7.1 in Gibbon and Balsam, 1981). As discussed above, the relation between interUS interval and US to US signaling is unknown. Second, evidence for US to US signaling in the present experiments was obtained when only one of the USs was signaled. In most conventional procedures all USs are signaled by the CS, and in Experiment 1 it was demonstrated that blocking by US to US signaling was prevented when all USs were signaled by a CS other than the preceding US. Third, in these experiments the CS almost entirely filled the interval between USs whereas in the typical case the CS is short relative to the inter-US time. This could be an important condition for blocking a CS from US to US signaling because within the train, the prior US provides as much information about the time of delivery of the next US as does the CS. This is not true when the CS is short relative to the interval between USs. Fourth, in the present experiments the train of USs was surrounded by long waits, which is not the case in the typical conditioning procedure. This could be important because the US to US interval was very short relative to the long waits. Such a procedure would be expected to establish each US as a highly predictive temporal signal for the next US in the train, which may enable the US to act like a blocking stimulus. Fifth and finally, the interval between USs (excepting the time between the feeding at the start of the session and the beginning of the train) was fixed rather than variable. In Experiment 3 blocking from US to US signaling was prevented by varying (among other things) the intervals between USs following the trial. In conventional conditioning procedures the interval between trials or USs typically is variable.

I now return to consideration of the topic brought out above, namely the relation of US to US signaling to trial spacing effects and US preexposure phenomena. Assuming that the five conditions discussed above are important ones for establishing US to US signaling, and subsequent blocking from this source, it is not possible to calculate the degree to which US to US signaling plays a role in conventional conditioning arrangements. Even in the face of these difficulties, however, there is evidence in the literature which tends to support the notion that trial spacing effects and the US preexposure phenomenon may depend in part on blocking or overshadowing by US to US signaling.

Trial Spacing

Jenkins, Barnes, and Barrera (1981) suggested that the trial spacing effect might be due to blocking by US to US signaling:

> One food delivery can serve as a signal for the next food delivery and can therefore compete with the autoshaping stimulus as a signal for food. In theory, the autoshaping stimulus would be subject to a greater degree of overshadowing (see Kamin, 1969) from a prior food delivery when trials are closely spaced, and this could account for the slower acquisition of autoshaped keypecking. (Jenkins et al., 1981, pp. 257-258).

Although Jenkins et. al. (1981) tested this possibility in three experiments (numbers 2, 3, and 4), they did not find positive evidence of the overshadowing or blocking which they hypothesized to occur. The experiments by Jenkins et. al. (1981) attempted to assess the possibility that US to US signaling was responsible fo the trial spacing effect by varying the temporal location of unsignaled USs with respect to the following trial, or, in another experiment, comparing acquisition with or without a US immediately prior to the trial. No significant effects of the temporal location of unsignaled USs with respect to the trial nor of the presentation of a single US immediately before the trial were found. They concluded that the trial spacing effect was not explicable on the basis of US to US signaling.

On the basis of the present results it is apparent that the conditions of those experiments were not sufficient to establish strong US to US signaling. The results of Experiment 3 suggest that to establish US to US signaling a high proportion of USs must be followed after a short time by a US. US to US signaling could be the cause of the trial spacing effect when the proportion of USs that are followed closely by another US is higher than that employed in Jenkins et. al's. procedures (i.e. when the temporal spacing employed in a conditioning arrangement applies to the entire series of trials in a conditioning session rather than to the immediate antecedents of widely spaced trial clusters).

The present series of studies provides evidence that the trial location effect arises as a result of blocking or overshadowing of autoshaped keypecking in which the blocking stimulus is the previous US. The possibility that US to US signaling plays a role in trial spacing therefore remains a salient one. In massed trials procedures, every US except the first is preceded closely in time by another US, and animal subjects may not show the acquisition of conditioned responding because the USs acquire signal value before the CS is able to do so. Assuming that USs which occur under widely spaced intervals do not signal each other as effectively as those occurring closer in time, it is not difficult to explain the trial spacing effect as a function of blocking by US to US signaling.

Evaluating the preceding hypothesis on the basis of the data either reported here or in the literature is, however, not feasible. For example, the experiments reported in this paper did not systematically explore the function relating the temporal separation of feedings to blocking by US to US signaling. The limits or boundary conditions over which US spacing and regularity can vary without disrupting US to US signaling are therefore unknown.

The near complete absence of conditioning in the groups in the present series of experiments that received the CS-US pairing late in the train, coupled with the results from Experiments 3 and 4, demonstrates that autoshaping is not necessarily a function of the relative waiting time ratio, since that ratio was held constant. Because the most direct explanation of trial spacing effects is based on the scalar expectancy formulation, it is necessary to ask what, if not scalar expectancy, is responsible for poor performance under conditioning regimes in which all US-US intervals are short. Interference generated from US to US signaling becomes a possibility at this point. This conclusion is supported by the results from Experiments 4 and 5 that showed that conditioning of the context, an alternative explanation for trial spacing effects, did not seem to play a role in the trial location effect and therefore is less likely to play a role in trial spacing effects.

Other evidence exists in the literature which supports the contention that US to US signaling plays a role in mediating trial spacing effects. Lucas and Wasserman (1982) explored the effect of changing local trial spacing in an autoshaping procedure involving heat as the US and baby chicks as subjects. Their results showed that the length of the previous intertrial interval affected responding to the autoshaping signal while the length of the interval prior to that did not. While they interpret their findings as suggestive of a moving average version of the scalar expectancy account, they did not include the control conditions necessary to rule out the possibility that lengthening the intertrial interval contributed to performance as a result of disrupting US to US signaling. Since the interUS intervals in their study were in the range of 6 to 96 seconds, it is possible that subjects learned that USs often occurred closely together and thus responded significantly less following the shorter (6 and 12 second) intertrial intervals.

More indirect evidence that US to US signaling plays a role in trial spacing effects comes from a study by Salafia, Mis, Terry, Bartosiak, and Datson (1973). These researchers studied the effect of increasing the intertrial intervals on conditioning of the nictitating membrane response of the rabbit, comparing fixed and variable ITI regimes. Although the range of values of ITI duration they employed did not include any values as small as the 10.5

second interval between USs in the present experiments, they nonetheless found significant effects of the degree of variation of intertrial interval. Specifically, the shape of the function relating ITI duration to acquisition scores was significantly different for constant and variable ITI groups. Subjects in the 60 second ITI condition acquired significantly faster than those in the 30 second ITI condition for groups that received fixed, but not variable, ITI durations. In fact for groups that received a variable ITI regime, acquisition scores were poorer at the 60 second value than at the thirty second value. The authors discuss the possibility that this difference was a function of temporal conditioning in the fixed ITI groups, which could also be expressed in terms of US to US signaling. For example, in temporal conditioning, the US is repeatedly presented at fixed intervals in the absence of an explict CS. This arrangement is, of course, highly similar to that employed in the present experiments.

This evidence is also indirect, and the effects reported by Salafia et al. (1973) are small. While this seems discouraging from the point of view of establishing the generality of the role played by US to US signaling, Experiments 5 and 6 provide a reason for the effects reported in the literature on this question to be small. In Experiments 5 and 6 it was demonstrated that CSs at any location would evoke conditioned responding providing that the first US in the train was preceded by the same CS. The procedures used in Experiments 1, 5, and 6 established clearly that the acquisition of CRs by the late block CSs depended on there being a CS-US pairing at the front of the train. This being the case, it is expected that when CS-US pairings are presented under variable ITI regimes, there should not be a large difference in responding to CSs following short ITIs and CSs following long ITIs. Only when the local temporal context of each CS-US pairing is held constant for a particular treatment, as was done in the present studies, would such differences be expected to emerge.

The preceding discussion has implications for the averaging of waiting times presumed to occur by scalar expectancy theory (SET). One of the assumptions of SET is that animal subjects average expectancies or waiting times not only within interreinforcement periods but across variable interreinforcement intervals as well (Gibbon and Balsam, 1981). According to SET, therefore, it should make no difference whether USs occur at regular or irregular intervals. Gibbon et al. (1981) present only indirect evidence that this is true, however. As long as acquisition can spread from CSs occurring at favorable locations to CSs occurring at unfavorable locations, the evidence provided by Gibbon et. al. is inconclusive. Behavior that appears to reflect the averaging of inter-US intervals may be due instead to the transfer of conditioning from favorable to unfavorable locations. The results of Experiments 3 and 4 suggest that fixed inter-US interval regimes may affect animal subjects in the autoshaping preparation in different ways than regimes in which the interval between USs varies. Unfortunately, the total time period over which USs were presented was not held constant between Groups B/3 Split Train and B/3 Random, and either or both of these factors may have led to the prevention of blocking in Group B/3 Random. Nevertheless, the analysis of trial spacing effects based on scalar timing may require reevaluation in the light of the present results.

In summary, the question of whether blocking of acquisition by US to US signaling plays a role in the trial spacing effect is an open one. The results presented here suggest new research into this possibility, but do not in and of themselves establish such a role. Moreover, it has been argued that the prevention of blocking acheived through signaling USs by the CS calls for a different set of procedures for investigating the effects of fixed versus variable interfood intervals on the acquisition of autoshaping. Because the studies currently available in the literature (Gibbon et al., 1977; Salafia, et al. 1973; Prokasy and Chambliss, 1960) did not control for the generalization of responding across locations in the train seen in the B/All group , the small effects reported are not firm evidence against the existence of larger effects when all trials are presented in the same location with respect to prior USs.

The US Preexposure Effect and Blocking by Contextual Stimuli

It has been repeatedly shown that US-only pretraining has a deleterious effect on subsequent acquisition of conditioned responding in autoshaping (Engberg, Hansen, Welker, and Thomas, 1972; Tomie, 1976a, 1981; Downing and Neuringer, 1976; Wasserman, 1973). In the past decade or so, the nearly unanimous consensus on the source or origin of this effect has been blocking due to contextual conditioning (Randich and Ross, 1984). The generality of the finding that manipulating contextual stimuli between pre- and main training alleviates much of the retardation suggests that a strong case has been made for the hypothesis that associative competition from contextual conditioning underlies the US preexeposure effect in autoshaping as well as other Pavlovian conditioning preparations (see Tomie, 1981, or Randich and Ross, 1984 for reviews). Although it is very likely that contextual conditioning plays a role, in US-only pretraining the USs might still come to signal one another and interfere with subsequent acquisition through blocking by US to US signaling. In this section the possibility that US to US signaling might also contribute to the US preexposure effect is considered.

The result that most strongly supports the context blocking account of the US preexposure phenomenon is the fact that a change in context between the pretraining phase and the acquisition test alleviates most of the retardation caused by US-only pretraining. Although this argues in favor of a context blocking interpretation of the US preexposure effect, it does not rule out the possibility that US to US signaling also contributes to the retardation of acquisition that follows US-only pretraining. This is because it is possible that US to US signaling may itself be context specific. This could occur if the blocking stimulus in the present experiments were not merely the prior US in the train but the compound stimulus composed of the prior US plus the static contextual cues. In this case, changing the context of conditioning might alleviate retardation caused by interference from US to US signaling. Of course, in the absence of any evidence this is pure speculation.

With regard to the literature, there are no reports addressing the US preexposure effect that consider US to US signaling (referred to either as such or as temporal conditioning) as a possible determinant of the phenomenon. Because so little is known about the domain of conditioning arrangements which will produce US to US signaling, it is impossible to know whether the typical pretraining procedures employed in US preexposure studies (i.e., VT-30" schedule of unsignaled US delivery) establish USs as signals for other USs. Given the number of special conditions used in the present procedures, it is not likely that relatively widely spaced random US presentations bring about the type of US to US signaling demonstrated in the present studies.

Thus as with trial spacing effects, neither the literature nor the present experiments provide a clear estimation of the importance, if any, of US to US signaling on the US preexposure phenomenon. It would be interesting to know whether the US preexposure effect could be attenuated by fully randomizing the presentation of the pretraining USs. Again, more research is needed to conclude anything other than that it is possible for US to US signaling to underlie the US preexposure and context blocking phenomena.

SUMMARY

The experiments reported in this thesis demonstrate a relatively new form of interference with Pavlovian conditioning from unsignaled USs occurring closely prior to the trial. Traditional analyses of interference with conditioning from unsignaled USs have looked to three sources to explain the interference: (a) the weakening of CS–US contingency caused by the unsignaled USs, (b) blocking of conditioning due to competition for associative strength from contextual stimuli, or (c) a degrading of the scalar expectancy ratio pertaining to the CS due to an increase in overall expectancy for the US. It was shown in several experiments that none of these accounts of the effects of unsignaled USs apply to the interference with conditioning demonstrated in the first experiment. Other experiments demonstrated additionally that the interference was not due to satiation from the added USs, nor from inhibition produced by the US, but from associative blocking in which the blocking stimulus is itself an unsignaled US which becomes conditioned as a signal for another US. This type of blocking stimulus is an unusual one not previously identified in the autoshaping literature and only once suggested in the broader literature on Pavlovian conditioning. The discussion

of this form of blocking suggests that it may play a role in understanding more conventional conditioning phenomena such as the trial spacing effect and the US preexposure effect.

Establishing USs as blocking stimuli was achieved through an unconventional conditioning arrangement in which all the USs in a conditioning session (except the first in each session) were presented in a closely spaced temporal train. The train of USs was both preceded and followed by long waiting periods in which neither CSs nor USs were presented.

Interestingly, blocking of conditioning to a CS within the train of USs was prevented if (a) all the USs in the train were signaled by the CS, (b) if the CS appeared both at the front of the train and at a later, normally blocked location, or (c) if the CS was originally presented at the front of the train and subsequently shifted in position to a late, normally blocked position. Experimental analysis of the prevention of blocking through these procedures revealed that blocking was prevented because conditioning the CS (when it was presented at the front of the train) resulted in a long term, and possibly irreversible, increase in the associability of the CS.

In the discussion section it was suggested that one way to understand both the blocking of conditioning by unsignaled USs and the prevention of this blocking through prior conditioning was given by a dual process theory of conditioning. In this type of theory changes in the associative strength of a stimulus (one process) occur separately from changes in the associability of the stimulus (the second process). According to this type of theory both associative strength and associability can be altered by experience with the stimulus in question. A detailed look at one formal theory of this type (Mackintosh's (1975) attentional theory) reveals that this theory appears to offer a promising opportunity to understand, within a single theoretical framework, both blocking and the prevention of blocking from the unconditioned stimulus in Pavlovian conditioning.

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