Conditioned Suppression and the Effects of Classical Conditioning on Operant Behavior

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INTRODUCTION

A defining feature of studies of classical conditioning is that the delivery of stimuli and the relationship between them are controlled by the experimenter independently of a subject's behavior (Black & Prokasy, 1972, p. xi). Pavlov (1927) was, of course, the first systematically to investigate the effects of such procedures on behavior. He presented one event (the conditioned stimulus: CS) regularly in a fixed temporal relationship with a second event (the unconditioned stimulus: US) which reliably elicited a response (the unconditioned response: UR). He found that eventually the CS came to produce behavior (the conditioned response: CR) which was similar to the UR. Pavlov's measures of this conditioning of an acquired reflex were simple but adequate. For example, when the UR was salivation caused by an irritant placed on the tongue, the CR was measured in terms of the number of drops of saliva resulting from the presentations of the CS. In this way conditioned responses were measured as they developed from a zero value on the first presentations of the CS to an asymptotic value when the stimulus was repeatedly presented with the US.

This chapter considers the effects of procedures of this nature in which events which signal the delivery of a US such as food or a shock are presented independently of an animal's behavior. However, the discussion is confined to experiments in which the effects are measured by the changes they produce in behavior which is maintained by response-dependent reinforcement. The dependent variable in such studies is provided by a comparison of the frequency with which *operant* responses are emitted during the Pavlovian CS and in its absence. A typical experimental situation is shown in diagramatic form in Figure 1. The top line shows the presentation of a continuous stimulus (e.g., a light) which is associated with a schedule of reinforcement. The fourth line shows the operant responses (e.g., lever presses) which are emitted during this discriminative stimulus, and the bottom line depicts the delivery of resultant response-dependent reinforcers according to an intermittent schedule, such as a variable-interval schedule. During the discriminative stimulus, and therefore while the subject is emitting operant responses, a second stimulus, such as a tone, is presented: this is shown in the second line of Figure 1. This second stimulus signals the delivery of a Pavlovian US such as electric shock (third line). The sec-
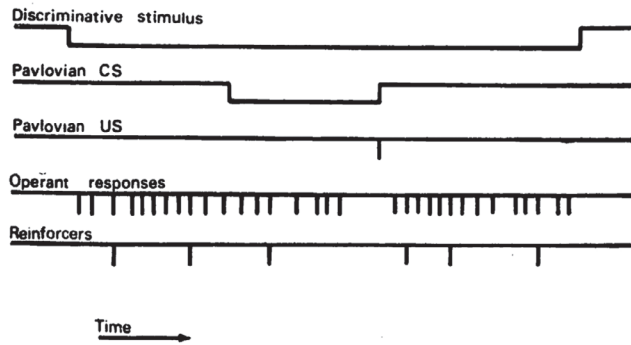
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Fig. 1. Diagram representing typical experimental arrangements in the studies discussed in this chapter.

ond and third lines therefore depict in this case a typical Pavlovian delayed conditioning procedure, which is superimposed on a situation in which operant behavior is maintained by occasional reinforcement. The only behavioral measure in this experiment is provided by the operant responses depicted in Figure 1. This is the case in most of the experiments discussed in this chapter, although in some studies *additional* measures are taken of autonomic activity (respondent behaviors) which occur during the CS or after the US, such as changes in heart rate.

The experiments to be discussed differ from conventional classical conditioning experiments, then, in two important ways. First, the behavioral measures are provided by operant rather than by traditional respondent behavior. Second, when the Pavlovian CS is presented, the subject is at that time emitting a pattern of behavior which is recognized (and controlled) by the experimenter. These differences in emphasis have not, however, prevented the collection of data of considerable importance for classical conditioning. Moreover, such experiments have brought a number of theoretical issues into sharp focus.

Clearly, there are many different interactions which may be studied within the general procedure discussed above. As Rescorla and Solomon (1967) have pointed out, the operant behavior may be maintained by a schedule of positive or of negative reinforcement, and the Pavlovian US may be either appetitive or aversive. These various interactions will be reviewed in this chapter. However, most of the research conducted in this area has studied the effects of an aversive US (specifically, shock) with the Pavlovian procedure introduced when operant behavior is maintained by schedules of food or water reinforcement. It is here that the most developed theoretical implications are to be found, and it is this area of research and discussion to which we therefore turn first. No attempt will be made in this chapter to provide a comprehensive

review of the truly vast body of literature reporting experiments in which Pavlovian procedures have been superimposed on operant behavior. The discussion is deliberately and strenuously selective, in the hope that general principles and problems may emerge more directly and more clearly.

THE ESTES-SKINNER PROCEDURE AND THE MEASUREMENT OF ITS EFFECTS

In 1941 Estes and Skinner reported the results of a study in which they exposed rats to an intermittent schedule of food reinforcement which would now be described as fixed-interval (FI) 4 min. When the rats' lever-pressing behavior had stabilized, a tone was presented for a period of 3 min (5 min in later conditions). As each period of tone ended, an unavoidable and inescapable shock was delivered to the rats through the grid floor. The delivery of both tone and shock was programmed independently of the rats' behavior, and the temporal relation between them makes it possible to term the procedure classical conditioning: the tone is thus a Pavlovian CS and the shock is a US. Unfortunately, the intensity of the shock was not reported in this early paper, but it must have been relatively mild because Estes and Skinner mentioned that it produced no noticeable disturbance in operant behavior when it was first delivered. However, as the repeated pairings of tone and shock continued, behavior during the tone became disrupted. The rate of responding during the tone fell until it was about one-third the rate during the same period "in control experiments." This is illustrated by cumulative records taken during the experiment, which show clearly the decrease in operant response rate during the period of tone in comparison with rates before and after the tone. The general finding that food-reinforced operant behavior decreases in frequency during a preshock stimulus has since been widely replicated in many different experimental conditions. The effect is sometimes called *conditioned suppression* (see detailed reviews by Davis, 1968, and Lyon, 1968). It is illustrated by the segments of cumulative record shown in Figure 2 (from Blackman, 1974) which show the operant behavior of a rat exposed to a variable-interval (VI) 30-sec schedule of food reinforcement, the delivery of which is shown by brief hatchmarks in the usual way. In the middle of successive 7-min periods, an auditory stimulus was presented for 1 min, during the whole of which time the pen on the cumulative recorder was deflected downward, although it

could still be stepped across the paper by an operant response.

At the end of each of these 1-min periods, a very brief shock was delivered. The record at the top of Figure 2 shows that the responding maintained by the VI schedule was completely eliminated during the preshock signal, for the record is horizontal during the 1-min deflection. Immediately after the shock, the animal resumed the steady rate of operant responding maintained by the schedule. The lower segment of the record shows that during another two 1-min periods of the noise the rat did not stop responding completely, although the response rate was lower during the noise than in its absence. Since the VI schedule remained in operation during these periods, responses might still occasionally be followed by a reinforcer (shown by a brief *upward* hatchmark on the record). Figure 2 therefore depicts complete conditioned suppression (top) and partial conditioned suppression (bottom) of operant behavior during a CS (noise) terminated by a US (shock).

In this area of research, it has been generally accepted that an appropriate measurement is a comparison between response rates during a CS and in its absence rather than the absolute reduction of response rates during the CS. This measurement is achieved by means of a *suppression ratio* or *inflection ratio,* but unfortunately there has been no general agreement about the best way to make this calculation. One simple method is to present the rate during the CS as a direct proportion of a control rate of responding (e.g., Stein, Sidman, & Brady, 1958). In this case, complete conditioned suppression is depicted by a ratio of 0; if there is no effect on response rate attributable to the CS, the suppression ratio is 1.0, and if the response rate *increases* during the CS, the ratio is greater than 1.0. However, another widely used ratio (e.g., Kamin, 1965; Rescorla, 1968) expresses the rate during the CS as a proportion of the sum of control and CS response rates. This results in a figure of 0 for complete suppression, .5 for no suppression, and greater than .5 for acceleration of responding during a CS. The use of these different calculations, and of others, is a potential confusion in this area of research (see Lyon, 1968). Moreover, as will be discussed later, the use of any relative rate measure such as these is not without its problems (Lea & Morgan, 1972).

INVESTIGATIONS OF CLASSICAL CONDITIONING PARAMETERS

Many investigators have found that the amount of conditioned suppression (however the suppression ratio is calculated) is a function of conventional parameters in classical conditioning (Davis, 1968). To mention two simple examples, Annau and Kamin (1961) showed that the amount of conditioned suppression in rats is an increasing monotonic function of the intensity of the shock US, and Kamin and Schaub (1963) have shown a similar effect of the intensity of the CS. Rescorla and Solomon (1967) have suggested that "it might very well turn out that instrumental responding is as sensitive, or perhaps even more sensitive, a measure of the effects of Pavlovian conditioning procedures than are the traditionally measured conditioned visceral or motor reflexes themselves." Although Rescorla and Solomon considered this possibility "somewhat ironic," it is certainly true that the conditioned suppression paradigm has been widely and successfully used in order to develop our understanding of classical procedures in general. Reviewing a great deal of such work carried out in his own laboratory, Kamin (1965) has claimed that "we are measuring respondent behavior indirectly, with a surprising quantitative sensitivity." It is not possible to review here the large body of literature in this tradition. However, as one example of current work,
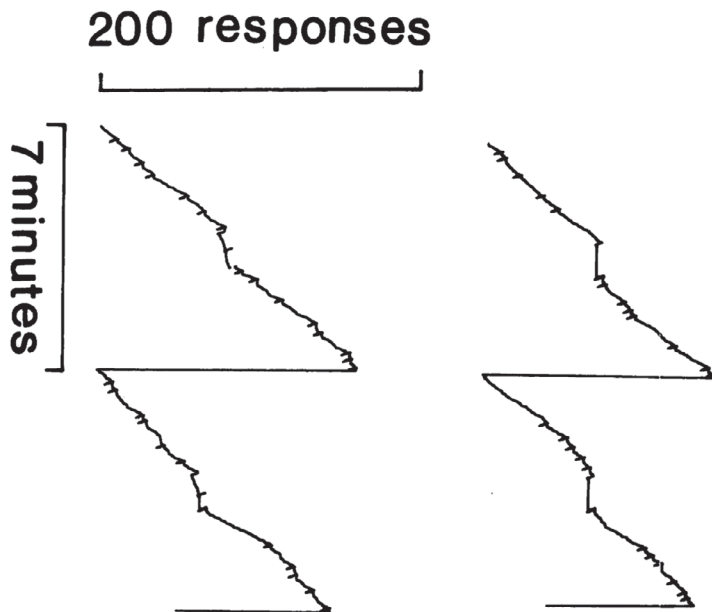
200 responses

Fig. 2. Cumulative records illustrating the effects on operant behavior of a stimulus ending with an unavoidable shock (conditioned suppression). The response pen is offset during the preshock stimulus; hatchmarks denote reinforcement.

Rescorla's investigations of the necessary and sufficient conditions for a stimulus to become a classical conditioned stimulus may be cited.

Rescorla's important work grew out of his theoretical discussion of the appropriate control procedures for Pavlovian conditioning (Rescorla, 1967). In this paper, he suggested that conventional procedures did not allow for the measurement of appropriate base lines against which to assess accurately the strengths of a conditioned response developed by Pavlovian procedures. For example, in some experiments the stimulus which becomes the conditioned stimulus has first been presented in such a way that it is explicitly never paired with the unconditioned stimulus. The temporal contingency between the CS and the US is then introduced in the conditioning phase of the experiment. Rescorla argued that traditional control procedures such as this fail to provide an unconfounded measure of the effects of the experimental contingency between the stimuli. He suggested that the only way in which this could be achieved was by means of what he termed a "truly random" control procedure. With this control procedure, the stimulus which is to become the CS and the US are first presented at the frequencies to be used in the conditioning phase, but entirely independently; it is therefore possible for them to be occasionally presented together *by chance*. Hence occasional contiguity between the two stimuli may occur, but no reliable contingency exists between them at this stage of the experiment.

Rescorla's empirical work has subsequently developed these ideas. He has shown, for example, that mere contiguity between two stimuli is in fact not sufficient for Pavlovian conditioning to develop. If a stimulus is to become a CS and thus elicit a CR, it now seems that it must, in simple terms, provide a subject with "information" about the occurrence of the US. In his truly random control, the occurrence of a CS provides no information about the occurrence of a US, for the probability of a US is the same both when a CS is presented and when it is not. On the other hand, in traditional delayed conditioning experiments, the occurrence of a CS provides information that a US is about to be presented; moreover, no US is presented without a preceding CS. One of Rescorla's elegant experiments (1968) has used the conditioned suppression paradigm to investigate the effects of these and of various intermediate relationships between a CS and a US, and its results are summarized in Figure 3. The CS was a 2-min presentation of a tone, and the US was shock. Small groups of rats were exposed to various relationships between these stimuli. The probability of a shock in a period
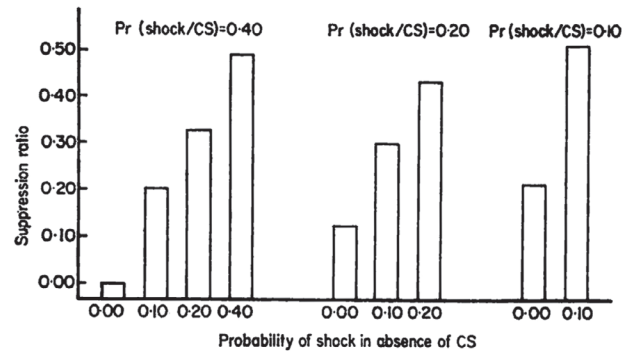

Fig. 3. Median suppression ratios for groups of rats as a function of the probability of shock in the presence and absence of the CS. A ratio of 0.00 denotes complete suppression, and .50 shows that the CS has no effect. (From Mackintosh, 1974, after Rescorla, 1968.)

of tone was specified for different groups as .40, .20, .10, or 0 (i.e., no shocks were delivered). Within these groups, subgroups of animals were exposed to varying probabilities of shock in periods when the tone was absent. Rescorla then measured the effects of the tone after these training conditions by superimposing the tone (without shocks) on food-reinforced operant behavior and measuring its disruptive effects. The dependent variable was expressed as a median suppression ratio, this being calculated by the formula which yields a ratio of 0 for complete conditioned suppression and .5 for no disruptive effect. Figure 3 shows the effects of the tone on the first day on which it was superimposed on the operant behavior of the various groups (four presentations for each rat). If the probability of a shock was the same both in the presence and the absence of a tone (Rescorla's truly random procedure), the tone had no suppressive effect. Thus suppression ratios are consistently at a value of approximately .5 whether the probability of a shock in the presence and in the absence of the tone was .40, .20, or .10. On the other hand, if shocks had initially occurred *only* during a period of tone (so that the probability of shock in the absence of the tone was 0), the tone caused relatively severe suppression of operant behavior. The amount of this suppression increases with greater probabilities of shock *during* the tone, for when the probability of shock in the tone was .10, .20, or .40, suppression ratios were approximately .20, .10, and 0 respectively. Figure 3 shows, then, that the tone suppressed operant behavior to the extent that it had been differentially associated with the occurrence of a shock, that is, in proportion to the difference between the probability of shock during the tone and its probability in the absence of the tone. The degree of classical conditioning in-

creased as the probability of the US during the CS became greater than the probability of the US in the absence of the CS, and not simply as the former value increased.

Rescorla has developed his account of the necessary and sufficient conditions for classical conditioning far beyond the basic idea indicated above (see, for example, Rescorla, 1969; Rescorla & Wagner, 1972), but it is not necessary to provide a more complete description here. Rescorla's important work on classical conditioning is based closely on his use of the conditioned suppression procedure. This procedure makes it possible to measure behavior (in the form of operant response rates) throughout both non-CS and CS periods, whatever the probability of the US in either of them. The demands for a sensitive and reliable dependent variable to show the effects of the quantitative differences in Rescorla's independent variables is met by the indirect measurement of classical conditioning through the frequency of *operant* responses.

Our understanding of classical conditioning procedures has therefore been significantly advanced by studies of their effects on operant behavior. The examples discussed here are representative of a very large body of research which has been carried out within this general strategy, and they illustrate its contemporary impact. The procedure has consistently proved to be robust, reliable, and sensitive, and so any inherent ironies may surely be readily tolerated by researchers in the field of classical conditioning.

INVESTIGATIONS OF OPERANT CONDITIONING PARAMETERS

In the research discussed in the previous section, the emphasis was placed on the way in which the processes of classical conditioning may be investigated by means of conditioned suppression procedures. The operant behavior which provides the only dependent variable in these studies is usually maintained by a simple schedule of intermittent reinforcement. Typically, a variable-interval schedule is used for this purpose, for, of course, such schedules maintain operant behavior over considerable periods of time, and the generally moderate and consistent rates of responding which they generate make it easy for the experimenter to measure any suppressive effect of a CS (as in Figure 2, for example). Also, of course, partial suppression of behavior maintained by a variable-interval schedule may have only minimal effects on the frequency of reinforcement obtained. If the operant behavior of the subjects in various experimental

groups is controlled by an identical procedure, we have seen that it is indeed possible to further the analysis of the necessary and sufficient conditions for classical conditioning to occur and to measure its strength as a function of specified independent variables. However, the amount of conditioned suppression during a preshock stimulus is not determined solely by such Pavlovian variables as the parameters of the conditioned and unconditioned stimuli and the contingencies between them. In this section other important variables are discussed which are related to the maintenance of the operant response on which the classical conditioning procedure is imposed.

Anything which affects the nature or strength of operant behavior may also affect the amount of disruption produced by a specified conditioned stimulus when it is superimposed on that behavior. This is perhaps not surprising, since conditioned suppression can be regarded as the result of pitting classical against operant conditioning effects. An important study which emphasizes this was reported by Stein, Sidman, and Brady (1958), who investigated the effects of varying the duration of a preshock stimulus through a range of 30 sec to 50 min and also examined the effects of varying the interval between successive stimulus presentations. Considerable variation was found in the amount of conditioned suppression produced by different combinations of these variables. However, neither of them proved to be a critical determinant in itself: instead, there was a high negative correlation between the amount of suppression and the *relative* duration of the preshock stimulus, i.e., the proportion of time in any session during which the CS was present. In considering ways in which this somewhat abstract temporal value might control the amount of conditioned suppression, Stein et al. noted that the behavior of the rats in their study was suppressed only to the extent that they did not thereby miss more than 10% of the total number of reinforcements which could be set up by the VI schedule. So, when a preshock stimulus (of any duration) was present for a relatively high proportion of the experimental session, complete suppression of operant behavior would have produced a substantial reduction in the number of reinforcements obtained. In these situations, only partial suppression of behavior was observed during the preshock stimulus. However, if a relatively short preshock stimulus was presented only rarely, the subjects could "afford" to suppress completely and yet still obtain at least 90% of the total possible reinforcers, and indeed complete suppression was observed in such situations.

Carlton and Didamo (1960) reported a study based

on that of Stein et al. (1958), but they varied the length of their experimental sessions so that the number of reinforcers actually obtained by subjects was constant throughout the various conditions of the experiment. Again it was found that the amount of conditioned suppression decreased as the relative duration of the preshock stimulus increased. Carlton and Didamo suggested that this reduction in the suppressive effect was due to "changes in response output which minimise the decline in reinforcement rate." This suggestion implies that behavior which is reinforced only occasionally will be less resistant to the suppressive effects of a preshock stimulus, for a "decline in reinforcement rate" resulting from suppression during a fixed preshock stimulus might not be so readily detected. An experiment by Lyon (1964) supports this hypothesis. Using pigeons as subjects, Lyon superimposed a preshock stimulus on both components of a multiple schedule in ·which two frequencies of reinforcement were programmed (*mult VI 1-min VI 4-min*) . It was found that the pigeons' behavior was more suppressed during the preshock stimulus when it was superimposed on the lower frequency of reinforcement than when it occurred during the component with the higher reinforcement frequency. Lyon therefore suggested that behavior which is reinforced relatively frequently is more resistant to disruption by a conditioned suppression procedure than is behavior which is reinforced only rarely. This has been corroborated by Blackman (1968b), who used response-pacing procedures (Ferster & Skinner, 1957) which controlled responding at approximately equal rates in two components of a multiple schedule, but in which the frequencies of reinforcement were controlled by two different VI schedules. This made it possible to identify the effects of reinforcement frequency on conditioned suppression more unequivocally than did Lyon's (1964) study, for in the latter the different frequencies of reinforcement produced different control response rates, a possible confounding effect.

If the conditioned suppression phenomenon is conceptualized as the outcome of a competition between a classically conditioned response with a fixed strength and the tendency to emit operant responses which are occasionally reinforced, the relative resistance of behaviors which result in frequent reinforcement may not seem surprising. Less predictable, however, is the finding that, when reinforcement frequency is controlled, rates of responding are differentially susceptible to conditioned suppression during a preshock stimulus. Blackman has shown in a series of experiments (1966, 1967, 1968b) that high rates of respond-ing are more suppressed during a preshock stimulus than are lower rates which obtain the same frequency of reinforcement. This conclusion was prompted by suppression ratios, but since these are relative measures of the responding during a preshock stimulus, it seemed possible that the differences in suppression ratio might have been merely artifacts of the different base line response rates. For example, if the absolute number of responses emitted during a preshock stimulus was constant whatever the base line response rates, then suppression ratios would inevitably suggest less suppression in the condition in which the preshock stimulus was superimposed on the lower rate. This was not the case, however. For example, in many conditions the absolute response rates during a preshock stimulus were higher when it was superimposed on the lower control rate than when it was superimposed on the higher control rate (Blackman, 1968b, Table 6). So, for example, one subject (rat 1) emitted 89 responses per min in the control conditions of one component (A) of a multiple schedule and 36 responses per min in the control conditions of the other component (B). The schedules in both components provided 2 reinforcements per min on average, but different response-pacing requirements were in operation in each component. During a 1-min period of tone which ended with a .5-mA shock the suppression ratios (response rate during CS divided by response rate in absence of CS) for this rat were .04 on component A and .60 on component B. These ratios reflected a mean rate of 5 responses per min in the preshock stimulus when it was superimposed on component A (high control rate) and 22 responses per min during the same preshock stimulus when it was superimposed on component B (lower control rate). Hence the relative differences in control response rates were reversed during the preshock stimulus, which supports the view based on suppression ratios that lower rates of responding are more resistant to disruption by a preshock stimulus than are higher rates.

The amount of conditioned suppression depends in part, then, on the frequency of reinforcement and on the rate of operant responding. The effects of classical conditioning procedures may therefore be dependent on the schedule of reinforcement on which they are superimposed. The importance of schedules in determining the behavioral effects of other independent variables requires no emphasis here, for it has been demonstrated in many other contexts, such as the effects of drugs (e.g., Kelleher & Morse, 1968) and the effects of unsignaled aversive stimuli (e.g., McKearney, 1972).

The effects of conditioned suppression procedures

have now been investigated with all the principal schedules of reinforcement. Lyon and Felton (1966a) studied pigeons' behavior maintained by variable-ratio (VR) schedules. They had expected that as the mean ratio requirement was increased from 50 to 100 to 200, the subjects would show more conditioned suppression, because the overall frequency of reinforcement would fall. In fact, however, the results of their experiment were inconclusive, for they found that the behavior maintained by all the VR schedules was quite insensitive to the conditioned suppression procedure. This may be because reinforcements were contingent upon the continued and sustained emission of responses with this schedule in a way that is not the case with variable-interval schedules. Fantino (1973) has pointed out that partial suppression during a preshock stimulus superimposed on a variable-interval schedule can have, within limits, virtually no effect on the rate of reinforcement. This is clearly not the case with ratio schedules. Fantino therefore regards the results of Felton and Lyon as being "readily interpretable." However, Blackman (1966) reported an experiment using rats as subjects in which VR 100 behavior was far from resistant to conditioned suppression: all three rats showed virtually complete conditioned suppression when the shocks (.5 mA, .2 sec) were introduced. Another three animals were "yoked" to these first three, i.e., reinforcements were made available to them by the delivery of reinforcements to the VR animals, so that they were in effect on a VI schedule with a mean interreinforcement interval identical to that of the ratio animals. These VI animals did not show such severe conditioned suppression, which emphasizes the susceptibility of the ratio animals to conditioned suppression in this experiment, in contrast to the resistance shown by Lyon and Felton's pigeons. The reasons for these inconsistencies remain obscure; one hesitates to invoke species differences, especially as pigeons and rats appear to be used interchangeably in other studies of conditioned suppression. Perhaps Fantino's (1973) suggestion that "it would have been interesting [in the Lyon and Felton study] to note whether conditioned suppression would have been obtained with high shock intensities" is useful, for it is possible that the shocks used by Lyon and Felton would not have suppressed other patterns of behavior in these pigeons.

The effects of conditioned suppression procedures have also been investigated with fixed-ratio and fixed-interval schedules. Lyon (1964) found that the effects of a preshock stimulus superimposed on FR 150 behavior in pigeons depended on how far the bird was advanced in its sequence of behavior when the

stimulus was presented. If this occurred just after reinforcement, Lyon observed complete suppression during the stimulus. If, when the stimulus was introduced, the bird had emitted more than 60 responses in the required sequence of 150, it continued responding until the next reinforcement and then suppressed completely until the end of the stimulus. If the stimulus began when the bird was between 20 and 60 responses into the required sequence, immediate suppression was sometimes seen and on other occasions the animal continued to respond until the next reinforcement was obtained. The initial resistance to suppression when the bird had completed more than 60 responses may perhaps be taken as support for Lyon and Felton's (1966a) report that variable-ratio behavior in pigeons is resistant to suppression, for with the variable schedule the imminence of the next reinforcement may always be as close as in those conditions of Lyon's fixed-ratio experiment when the behavior was found to be resistant to suppression. Similarly, with variable-ratio schedules, the birds do not show postreinforcement pauses as they do on FR 150. Another study by Lyon and Felton (1966b) found that birds exposed to FR 25 (and to a lesser extent FR 50) did begin to respond again *after* a reinforcement had been obtained during a preshock stimulus. The birds therefore often obtained several reinforcements during the stimulus, and so to that extent could also be described as resistant to conditioned suppression.

The crucial relationship between the onset of a preshock stimulus and the imminence of reinforcement has also been suggested with fixed-interval schedules. For example, Blackman (1968a) discussed the behavior of one subject (rat 1) which was exposed to a FI 20-sec schedule. A 1-min preshock stimulus was presented in such a way that the next reinforcement became available 5 sec after its onset (and, therefore 25 and 45 sec after the onset). When the shock which ended this stimulus was of .5 mA for .2 sec, the rat responded long enough into the stimulus to obtain the first two of these reinforcements (i.e., for 25 sec), and then suppressed completely until the end of the stimulus. When the shock was increased to 1.6 mA, responding continued only long enough for the first reinforcement to be obtained (i.e., for 5 sec). With a shock setting of 3.0 mA for .5 sec, all responding was suppressed immediately the preshock stimulus was presented, even though a reinforcement would become available only 5 sec later. A study by Lyon and Millar (1969) also suggests that the imminence of reinforcement in an FI schedule may attenuate conditioned suppression. In the interreinforcement intervals of an FI 2-min schedule, a preshock stimulus of 30 sec was

presented 30, 60, or 90 sec after the preceding reinforcement. It was found that there was marked suppression of responding during the stimulus when it was presented early in the interval, but no suppression when the stimulus occurred late in the interval.

Preshock stimuli have also been superimposed on behavior maintained by a schedule which differentially reinforces a very low rate of responding (DRL). In some circumstances it has been shown that responding on this schedule increases in frequency during a preshock stimulus. For example, Blackman (1968a) exposed rats to a multiple schedule, of which one component was a DRL 15-sec schedule and the other generated higher response rates. In all conditions of the experiment, this second pattern of behavior was suppressed during a preshock stimulus. However, when the stimulus ended with a relatively mild shock (.2 mA for .5 or 1.0 sec), the DRL behavior increased in frequency during its presentation, although with higher intensities of shock the more usual suppressive effect was found. The acceleration of DRL responding during a stimulus which ends with a mild shock is illustrated in Figure 4, which shows the cumulative records of three rats exposed throughout each experimental session to a DRL 15-sec schedule. A tentative suggestion has been made (Blackman, 1968a) that the acceleration effect on the DRL responding was attributable to a disruption of the collateral behavior which appeared to mediate the lever-pressing behavior. These stereotyped sequences of behavior were not formally measured in the experiment, but they characterized the DRL behavior in control conditions. During the preshock stimulus, however, the collateral behaviors seemed to be quickly disrupted, and lever pressing then occurred in their
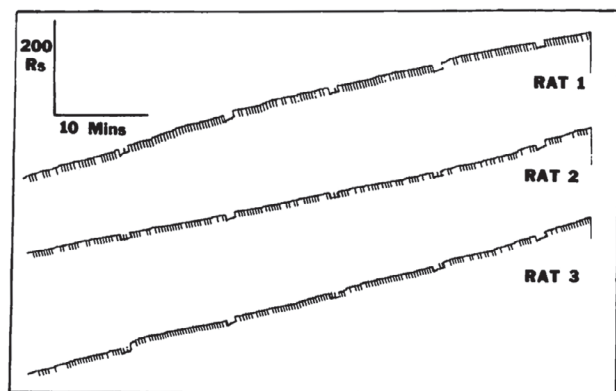

Fig. 4. The accelerative effects of a preshock stimulus on responding maintained by a schedule which differentially reinforces a low rate of lever pressing (DRL 15 sec). The response pen is offset during the preshock stimulus; hatchmarks denote reinforcement. (Unpublished data of Sanger & Blackman.)

absence and at a higher frequency than in control conditions.

In an experiment which employed a two-lever situation (Blackman, 1970a), rats were exposed to a schedule in which a response on lever B was followed by reinforcement if a preceding response on lever A had been made at least 5, 10, or 15 sec before. When a preshock stimulus was superimposed on the behavior generated by this schedule, it was found that the frequency of timing attempts, i.e., of A-to-B sequences, decreased during the stimulus. This had also been found in a similar experiment by Migler and Brady (1964). When the delay required was 5 sec, there was no change in the distribution of A-to-B times during the preshock stimulus. Thus although the frequency of timing attempts decreased, their accuracy was not impaired, again replicating a finding by Migler and Brady (1964). However, when the required A-to-B delay was 10 or 15 sec, the distribution of A-to-B times changed during the preshock stimulus, there being more shorter intervals. Also noticeable (especially with the 15-sec-delay requirement) was an increased proportion of inappropriate B responses, i.e., B responses which were made without a preceding A response to initiate a timing attempt. The disruption of timing efficiency and the increase in appropriate B responses led in one case to an overall acceleration of B responses in comparison with control conditions, in spite of the decreased frequency of appropriate timing attempts. This accelerative effect may be analogous to the acceleration reported with a single-lever DRL schedule. A generally similar effect was reported by Blackman and Scruton (1973a), who superimposed a preshock stimulus on a two-lever counting schedule. In this case, rats were required to make at least a specified number of successive responses on lever A before switching to lever B to produce reinforcement, and there was a shift to shorter sequences of responses on lever A during the preshock stimulus.

Hearst (1965) has reported a deterioration in discriminative control as a result of the Estes-Skinner procedure. He superimposed a preshock stimulus on periods of intermittent reinforcement, and found that the operant behavior was suppressed in the usual way during this stimulus. However, the rats were also exposed to periods when no reinforcement was possible (extinction). The preshock stimulus never occurred during periods of extinction, but the deterioration in discriminative control reported by Hearst took the form of an increase in responding during these periods. Hearst related this finding to the Pavlovian concept of disinhibition. However, it should perhaps be mentioned that two subsequent experiments have

failed to replicate his findings (Blackman & Scruton, 1973b; Weiss, 1968). In the former case, there was no increase in responding during periods of extinction, even when the preshock stimulus was subsequently presented during extinction periods as well as during the periods of intermittent reinforcement. The reasons for these potentially important inconsistencies between experiments are not clear as yet.

It is clear that the amount of suppression produced by a given preshock stimulus depends crucially on the nature of the schedule which maintains the operant behavior on which it is superimposed. Indeed, in some circumstances (albeit limited to fairly stringent timing schedules) a preshock stimulus will lead to an increase in the rate of food-reinforced operant responding. Certain familiar schedules of reinforcement, particularly variable-interval, provide a base line of behavior against which the effects of classical conditioning parameters can be readily assessed. However, it is also the case that, when classical conditioning procedures are held constant, substantial differences in the effects of a conditioned stimulus may emerge as a function of the precise schedules of reinforcement which maintain the operant behavior, differences not only of degree but even on occasion of direction.

MEASUREMENT OF CONDITIONED SUPPRESSION

We have already noted that most workers have measured conditioned suppression by comparing the response rate during the preshock stimulus with the control rate of responding, i.e., in the absence of the preshock stimulus. We may continue to regard the different formulae which have been used to make such a comparison as no more than tedious and potentially confusing. However, Hoffman (1969) and Millenson and de Villiers (1972) have suggested that the use of relative measures has not been adequately justified. A relative measure may make it easy to compare conditioned suppression of different patterns of operant behavior, but this entails an arbitrary assumption: "Measurement by relative suppression presupposes that under constant experimental conditions the warning signal will produce the same relative decrement independent of the rate of the responding at the moment of the warning signal presentation" (Hoffman, 1969, p. 68). There is now ample evidence that this assumption is false, as shown in the previous section. Suppression ratios obtained in experiments in which the same preshock stimulus is superimposed on different rates of operant behavior are not identical (Black-

man, 1966, 1967, 1968b). Such a finding offers the investigator two very different interpretations (Blackman, 1972):

1. A suppression ratio may always reflect accurately the strength of a classically conditioned response elicited by the conditioned stimulus. In other words, the more severe the disruption of operant behavior (as expressed by a suppression ratio), the greater is the strength of the CR. If this is true, different strengths of CR are developed by a uniform procedure when it is superimposed on different operant response rates. Why this should be so remains unexplained, although it has often been suggested in a more general context that the effects of any independent variable depend on the nature of ongoing behavior as controlled by schedules of reinforcement (e.g., Dews, 1963).

2. A standard classical conditioning procedure may always result in a CR of uniform strength. Different suppression ratios describing the effects of a preshock stimulus on different patterns of operant behavior may then result from the fact that this uniform conditioned response interacts differently with these patterns of behavior. According to such a view, the suppression ratio is therefore not an uncontaminated reflection of the strength of a CR.

It is difficult to decide between these alternatives, and initial preferences may reflect whether one's basic allegiance is to the study of classical conditioning or of operant conditioning processes. Given this problem of interpreting suppression ratios, however, it would seem only prudent to support inferences based on these ratios by absolute data whenever possible. Thus in the case discussed in the previous section, suppression ratios suggested that high response rates were more disrupted by a preshock stimulus than were lower rates of responding. Corroborative evidence was provided by the absolute data, which showed that the stimulus was accompanied by fewer responses (in absolute terms) when superimposed on normally high response rates than when superimposed on normally lower rates. These two forms of data suggested that a differential effect is attributable to the patterns of operant behavior.

In many cases of interactions between a classical conditioning procedure and different patterns of operant behavior, the dilemma outlined above can be regarded as unimportant, for research interest may focus principally on the details of schedule control and its disruption. The matter can be of great practical significance, however, as may be illustrated by an example. Figure 5 shows data obtained from one rat which was exposed to a FR 10 schedule of food rein-
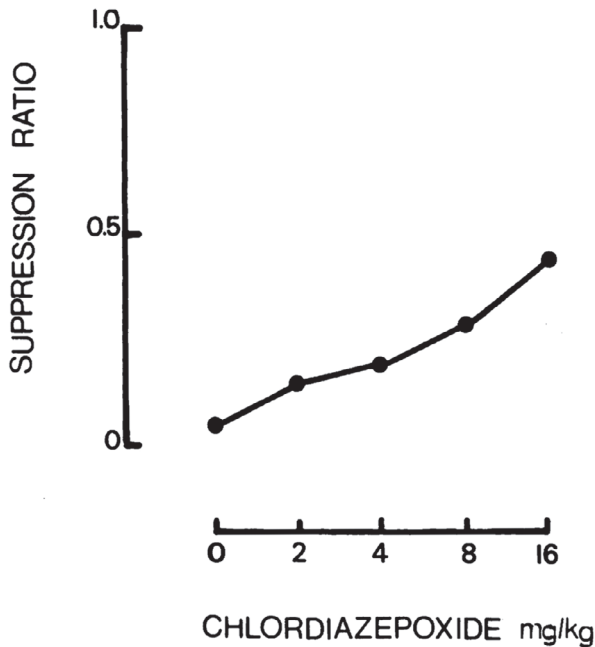
Fig. 5. The effects of various dosages of chlordiazepoxide on conditioned suppression of a rat's responding on a FR 10 schedule. Complete suppression = 0; no effect = 1.0. (Unpublished data of D. Sanger.)

appears: does the orderly effect of increasing dosage on suppression ratios reflect (1) progressive reductions in the strength of the underlying conditioned response, or (2) merely contaminations produced by a changing control base line, with the strength of the conditioned response remaining unchanged? Although it may be difficult to answer such a question, it is surely clear that informed interpretation of the drug's effects demands absolute as well as relative data. Nevertheless, experimental reports continue to emphasize suppression ratios and frequently fail to supplement these by absolute rates in the presence and absence of a conditioned stimulus.

A further complication arises whenever any simple measure of conditioned suppression is reported, whether this be in the form of relative or of absolute response rates during a preshock stimulus. We have noted previously that a stimulus which ends with a shock is a conditioned stimulus within the Pavlovian delayed conditioning paradigm. With traditional Pavlovian procedures, some form of temporal discrimination usually develops within such a CS, the conditioned

forcement. When this behavior had stabilized, a conventional conditioned suppression procedure was introduced, the details of which are not important here. The rat was then tested after various injections of the minor tranquilizer chlordiazepoxide. Figure 5 plots the suppression ratios which were obtained with the various doses, these being calculated by Stein, Sidman, and Brady's (1958) formula: SR = CS rate/Control rate. It seems clear that increasing doses of the drug have an increasingly attenuating effect on conditioned suppression. However, with a relative measure such as this, these changes may be produced *either* by changes in response rate during the CS or by changes in its absence. Figure 6 shows the absolute response rates in these two periods after each dosage of the drug. The open points display the drug's effects on response rates during the preshock stimulus (FR 10/CS), and the closed points show response rates in its absence. Clearly, the effects of the drug are by no means as simple as at first they may have seemed on the basis of the suppression ratios in Figure 5. In fact, the ratios change as a result of changes in response rates both within the CS and in control conditions. With lower dosages, increases occur in both response rates. The differences between the effects of 8 mg/kg and 16 mg/kg, however, can be seen to be almost entirely due to differences in control rates, with little change in CS rates. The dilemma outlined earlier therefore
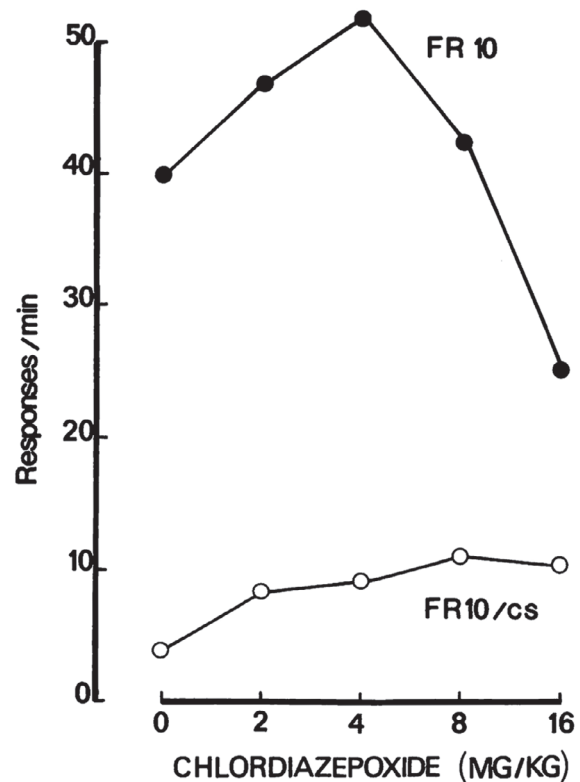

Fig. 6. The effects of chlordiazepoxide on conditioned suppression. The data are those which are expressed in the form of suppression ratios in Figure 7, but are here plotted in absolute terms, i.e., as response rates during the preshock stimulus (FR 10/CS) and rates in its absence (FR 10). (Unpublished data of D. Sanger.)

response eventually being characteristically elicited only toward the end of the CS (i.e., just before the US). A similar temporal discrimination has sometimes been reported with conditioned suppression. For example, Hendry and Van Toller (1965) reported that initial sustained suppression throughout a preshock stimulus was superseded by a pattern in which the suppression occurred only in the second half of the stimulus. In some cases, response rates during the first half of the stimulus in fact *increased* in comparison with control conditions. However, such temporal patterning has not been reported consistently in the literature, even in studies in which a preshock stimulus has been superimposed on operant behavior repeatedly. For example, Stein et al. (1958) remark that the type of response patterning within a fixed preshock stimulus was "not necessarily invariant from one stimulus presentation to the next." This is a further example of an inconsistency in the literature which has not yet been resolved. The development of temporal patterning may depend on a number of variables, such as the relative duration of the preshock stimulus, the intensity of the shock, the number of conditioning trials, and the nature of the schedule which maintains the operant behavior.

Unrecorded temporal patterning within a preshock stimulus could have a considerable contaminating effect on reported results. Millenson and Leslie (1974), for example, argue that a drug which appears to alleviate or enhance conditioned suppression might do so principally by affecting the nature of any such temporal discrimination. There would appear to be two ways of counteracting this possible contamination. The first is to vary the duration of the preshock stimulus from trial to trial, although still ending each stimulus presentation with a shock. Millenson and Hendry (1967) found that such a procedure did result in consistently suppressed responding during the stimulus. An alternative expedient is to use a conditioned stimulus of fixed duration in the usual way, but to deliver shocks at unpredictable moments throughout the stimulus and not merely as the stimulus ends. This procedure has been used occasionally. For example, Azrin (1956) included it (termed by him "VI uncorrelated shock"), and his cumulative records reveal consistent suppression throughout the stimulus associated with shock. More recently, Bond, Blackman, and Scruton (1973, Experiment 2) used the procedure. In this experiment the response rates were not entirely consistent throughout the stimulus associated with shock, but the inconsistencies may have resulted from the suppressive effects of the procedure on adjunctive licking which had reliably developed in

this experiment: certainly, there was no evidence of an orderly temporal patterning during the stimulus.

Of course, the delivery of shocks at unpredictable moments during a stimulus is strongly reminiscent of Rescorla's procedures reviewed earlier, although in these studies shocks and another stimulus were associated only before operant conditioning occurred, and only the CS was subsequently superimposed on operant behavior. Nevertheless, a complication even in presenting shocks at random moments during a stimulus emerges from one of Rescorla's studies (1968). He found that response rates were not consistently suppressed even when the conditioned stimulus was superimposed on variable interval behavior. There was greater suppression during the *initial* parts of the stimulus, with less in the later parts (i.e., the opposite of Hendry & Van Toller's 1965 results using a conventional preshock stimulus). Rescorla suggested that this effect may reflect the fact that the onset of a CS is more discriminable than its continued presence. A second possibility mentioned by Rescorla, however, brings us full circle, for he suggests that his differential suppression within a CS may be

> an artifact of the measuring technique. A VI schedule of reinforcement is such that the longer [a subject] has refrained from pressing, the higher the probability that its next press will be reinforced. Thus the longer [the subject] suppresses, the more "pressure" the base-line operant schedule places on it to respond. (Rescorla, 1968, p. 5)

Rescorla therefore goes on to suggest that the strength of the classically conditioned response may be constant throughout the CS: only the tendency to emit an operant response changes. This suggestion is clearly based on the second interpretation of conditioned suppression discussed toward the beginning of this section.

The measurement of conditioned suppression is fraught with difficulties, some of which pose interesting dilemmas. There is scope for ambiguity even when responding is totally suppressed during a preshock stimulus. For example, Lyon (1965) claimed that a change in base line response rate is not sufficient to change the amount of conditioned suppression. However, in the first phase of his experiment, Lyon used a procedure which resulted in complete conditioned suppression, and he then found that complete suppression still occurred when the base line response rate was increased. Subsequent research (e.g., Blackman, 1968b) has shown that increases in base line response rate lead to an *increase* in the amount of conditioned suppression. Since this effect could not

be shown in Lyon's experiment because of a "ceiling effect," he was therefore led to a general conclusion which was false. Problems of measurement in studies of conditioned suppression must therefore be borne in mind constantly in this area of research. Sometimes a simple suppression ratio in one sustained experimental situation may not be the most useful measure. For example, Fleshler and Hoffman (1961) investigated the stimulus generalization of conditioned suppression with pigeons. First, complete conditioned suppression was obtained during a 1000-Hz tone which preceded a shock. Then tones of different frequencies were presented in a generalization test in extinction conditions (i.e., no tone ended with shock). At first, the stimulus generalization gradient, which was measured by suppression ratios, was flat, there being almost complete conditioned suppression during all the tones. However, as testing proceeded, the gradient sharpened, the suppression ratios during the tones which were most different from the previous CS showing that these stimuli were the first to lose their control over behavior. Thus the flat gradient first obtained did not reflect uniform effects of the different test stimuli on behavior, and Fleshler and Hoffman's extinction procedure made it possible to identify their different degrees of behavioral control in spite of an initial "ceiling effect."

Although no simple measure of conditioned suppression is entirely satisfactory, many problems of interpretation may be overcome by using measures of absolute response rates during a preshock stimulus as well as the relative measures provided by suppression ratios, and in some circumstances by using repeated tests in changing conditions (as in Fleshler & Hoffman's 1961 experiment). The most important conclusion to be prompted, however, is that the most appropriate measure of conditioned suppression in any experiment should always be considered carefully.

SOME INTERPRETATIONS OF CONDITIONED SUPPRESSION

Why is positively reinforced operant behavior usually suppressed during a stimulus which is associated with shock? Three major explanations for this phenomenon will be considered here: operant behavior is suppressed because (1) other behaviors resulting from the procedure interfere with it; (2) the procedure generates an emotional state which affects the underlying motivational state of the subject; (3) the procedure allows for occasional adventitious punishment of the operant behavior. It is not always easy to keep these

three accounts separate, and any attempt to do so results in some arbitrary decisions. The discussion continues to be confined to the effects of a preshock stimulus on food-reinforced behavior. The extension of the theories to other examples of classical conditioning effects on operant base lines will be considered subsequently.

The Interference Hypothesis

The possibility that other behaviors interfere with ongoing operant behavior to produce conditioned suppression has been suggested in terms both of competing respondent behavior and of competing operants, although the former has received by far the more attention.

We have seen in a preceding section of this chapter that conventional Pavlovian conditioning parameters such as the intensity of the CS and the US determine the severity of conditioned suppression, so that the phenomenon has been frequently studied as an example of Pavlovian conditioning. Kamin (1965) has expressed a widely held view that "the most obvious assumption has been that the interference with behavior, which serves as our measure, is largely the result of incompatibility between respondents elicited by S_1 [the pre-shock stimulus] and the ongoing behavior."

The empirical status of this interfering respondents hypothesis is open to some doubt. First, it is necessary to specify the behaviors said to be conditioned during the preshock stimulus which are supposed to interfere with the operant behavior. Second, it remains necessary to show why and how any such behaviors are incompatible with the emission of an operant such as pressing a lever. There are several obvious contenders in answer to the first of these questions, but surprisingly little systematic work has been carried out in an attempt to monitor changes in autonomic activities to see if their intensities vary with the amount of suppression of operant behavior. On a gross level, traditional signs of autonomic activity such as defecation, urination, piloerection, and freezing of motor activity have frequently been discussed in the context of conditioned suppression. In an early experimental program by Brady and his associates (see, for example, Brady, 1951) the effects of a preshock stimulus were measured either in terms of the suppression of operant behavior with one group of animals or in terms of gross changes in these autonomic activities. Similarly, Hunt and Brady (1955) commented on such activity during a stimulus which precedes an unavoidable shock. There seems little

doubt that signs of autonomic activity such as these do characteristically accompany the early stages of many conditioned suppression experiments. However, Millenson and de Villiers (1972) have suggested that these signs seem to decrease with continued testing, although their comment is based on informal observations which deserve to be quantified systematically. Certainly in later stages of experiments suppression of operant behavior does appear to persist when gross signs of autonomic arousal are minimal or nonexistent.

There have been many studies of other more constrained respondent changes resulting from the delivery of a preshock stimulus (see, for example, the review by Weiskrantz, 1968). Two experimental programs which have related such changes to simultaneous suppression of operant behavior are particularly interesting. In the first of these (de Toledo & Black, 1966) the heart rates of rats were recorded. It was found that changes in heart rate did occur during the preshock stimulus, but they developed less quickly than did the suppression of operant responding. Moreover, the changes in heart rate were much more variable and of shorter duration than the operant suppression. This finding has been supported in a study by Brady, Kelly, and Plumlee (1969), in which the heart rate and blood pressure (both systolic and diastolic) of rhesus monkeys were monitored throughout the development and maintenance of conditioned suppression. During the preshock stimulus, there were certainly changes in these autonomic indicators. Again, however, suppression of the operant behavior developed before any detectable and reliable changes in heart rate and before changes in blood pressure. It was impossible to identify any consistently similar variations in the dependent variables in this study: with one subject changes in heart rate even appeared to be inversely related to the amount of conditioned suppression of operant behavior. On frequent occasions the two measures of blood pressure showed divergent patterns of conditioned reactions. The results of this experiment are illustrated by data from one subject in Figure 7. This shows the percentage changes in each of the four behavioral measures, expressed for each of the successive minutes of the 3-min preshock stimulus. Selected conditioning trials are shown. Reliable suppression of operant behavior developed before any consistent disruption in autonomic activities. The lack of consistent covariation between the measures can also be seen. This monkey also shows the development of a temporal discrimination in the conditioned suppression of operant behavior, as discussed earlier. This began to develop by the 16th trial, and

eventually took the form of only slight suppression in the first minute of the stimulus, with almost total suppression in the second and third minutes. However, measures of autonomic activity fail to show this biphasic pattern. It is also worth noticing that on some trials (e.g., trials 18 and 31 of those shown) lever pressing occurred more frequently in the first minute of the stimulus than in control conditions—the effect reported by Hendry and Van Toller (1965) and discussed earlier. Again, there is no characteristic patterning of autonomic activity which reflects this distribution of operant responses during the preshock stimulus.

On the basis of their data, Brady and his associates concluded that the operant and autonomic effects of their experiment were causally independent, although doubtless related in complex ways. In the most general terms, they suggested that their finding "reflects unfavorably upon theoretical formulations that emphasize either the causal interdependence of behavioral and physiological events or the primacy of either one."
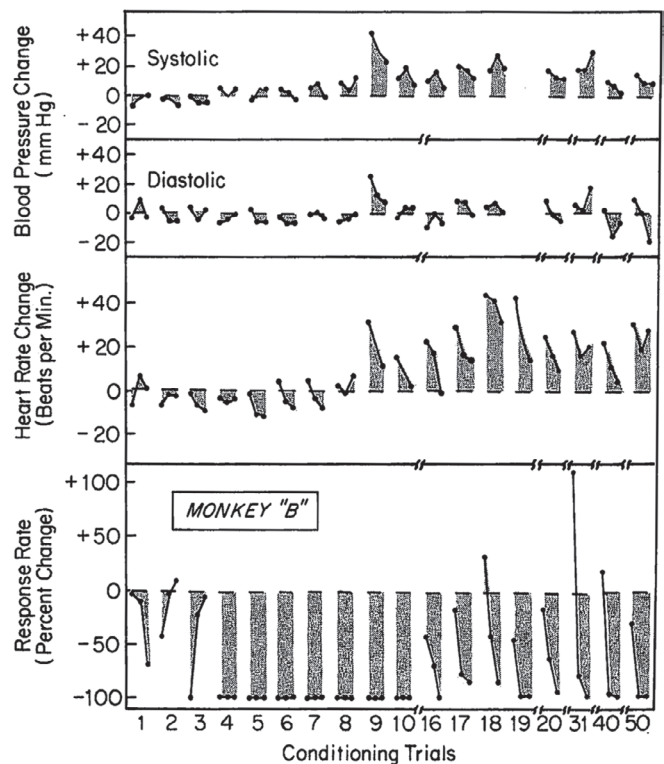

Fig. 7. Changes in blood pressure, heart rate, and lever-pressing response rate of a rhesus monkey during the 3 min of a preshock stimulus. The zero points represent control values in the absence of the preshock stimulus. (From Brady, Kelly, & Plumlee, 1969.)

Of course, in the context of the interference hypothesis of conditioned suppression it would always be possible to suggest that experimenters have failed to measure those respondents which do have a disruptive effect on operant behavior. Nevertheless, the evidence at present points unequivocally to the conclusion that conditioned respondents may accompany but do not cause conditioned suppression. In any case, even if some respondent were to be identified which varied in direct proportion to variations in operant responding, it would be by no means clear why it should be physically incompatible with that responding, the second necessary step if the interference theory is to be convincing. Further difficulties for this hypothesis are presented by the differential disruption of various frequencies and patterns of operant responding which was reviewed in an earlier section, for it is not obvious why any interfering respondent behavior should be more incompatible with some patterns and frequencies of operant responding than with others. This is, of course, particularly true when operant response rates are similar but reinforcement frequencies differ. Nevertheless it would certainly be of great interest to monitor autonomic changes when a preshock stimulus results in differential suppression of operant behavior. For example although operant and respondent behavior may not be functionally related on a 1:1 basis during a preshock stimulus, it would be interesting to discover whether the two classes of behavior are relatively resistant to disruption in the same circumstances (e.g., in situations which generate low operant response rates or with high reinforcement frequencies). Experiments such as this might have the greatest relevance in the general study of the relationships between autonomic processes and operant behaviors and of the relationship between physiological events and directly observable behaviors.

There remains one pattern of behavior not yet fully discussed but whose occurrence during a preshock stimulus might certainly be physically incompatible with lever pressing. Rats frequently crouch or "freeze" when shocked, and such behavior might occur during a preshock stimulus. Discussion of this possibility has been delayed, since it would be difficult to assert that this would necessarily be an example of a competing *respondent*. Leaving aside the question of whether such skeletal behaviors can be classically conditioned (see Chapter 3), it is possible that they might develop or be maintained as a result of their consequences, and hence should be regarded as competing *operant* behavior. In other words, adopting certain postures such as "freezing" might minimize

the aversiveness of a shock when it is delivered, as Weiskrantz (1968) has suggested.

"Freezing" behavior during a preshock stimulus has been investigated with pigeons by Stein, Hoffman, and Stitt (1971). They used ethological recording techniques to measure general behavior which occurred in addition to operant key pecking and found that there was a marked decrease in all overt activity (including key pecking) during the stimulus. In this experiment it is unlikely that such a general inhibitory effect in behavior was maintained by an unprogrammed instrumental contingency, since the shock was delivered through wing bands.

Whether any "freezing" responses during a preshock stimulus should be regarded as competing respondents or competing operants, this general interpretation of conditioned suppression is open to the objections discussed above. As with other putative competing responses, even if they occur reliably and consistently, it is not clear whether they interfere with recorded operants and thereby cause their suppression or are merely a reflection of the same process which causes such suppression.

Motivational Explanations

Many researchers have suggested that a preshock stimulus produces a change in the motivational state of a subject, which in turn leads to conditioned suppression. In recent years, Estes (1969 p. 80) has suggested that

a stimulus which has preceded a traumatic event, e.g., shock, . . . acquires the capacity of inhibiting the input of amplifier elements from sources associated with hunger, thirst and the like. If then, while the animal is performing an instrumental response for, say, food reward, this conditioned stimulus is presented, the facilitative drive input will be reduced and so also the probability or rate of the instrumental response.

A preshock stimulus may therefore be said to produce anxiety, which can be regarded as a motivational force which reduces positive motivation for reinforcement and thereby decreases the frequency of operant behavior.

A similar argument may also be developed from the description of conditioned suppression as resulting from a "conditioned emotional response" (CER). Thus Hunt and Brady (1951) hypothesized "an internal state underlying the behavioral reaction," and Kamin also used the term "CER" frequently (e.g., 1965). However, it is not consistently clear whether

either Hunt and Brady or Kamin wish to emphasize the adjective *emotional* sufficiently to demand that their theories be considered under the present heading rather than the previous one; for Kamin, at least, has consistently conducted research which could be said rather to emphasize the "conditioned . . . response" as the behavioral outcome of Pavlovian conditioning rather than as a motivational state. In their interesting paper, Millenson and de Villiers (1972) suggest that this "failure to consider that the CER is an emotional phenomenon" has been a barrier to the adequate understanding of the effects we have been discussing. These writers seek to develop Skinner's (1938) statement that emotion is "a state of strength comparable in many respects with a drive" (p. 407) and to argue that conditioned suppression results from "a negative drive activity," a view similar to that of Estes. Thus "when the signal for shock [is] presented the rat's hunger might be temporarily suspended and 'suppression' is the natural consequence of food (as well as all other positive reinforcers) having temporarily lost its reward value" (Millenson, 1971, p. 229).

A motivational decrement theory such as this directs research attention to questions somewhat different from those discussed so far. Clearly, a stimulus which precedes a shock of a given intensity will have a greater suppressive effect, according to this theory, if it is superimposed on behavior which is relatively weakly motivated. In this context, Millenson and de Villiers (1972) discuss experiments in which they varied the deprivation conditions for subjects exposed to a preshock stimulus. The results for one of these are shown in Figure 8. Groups of rats were exposed to a random-interval 60-sec schedule of food reinforcement in two conditions on each day: first when 9 hr food-deprived (prefeeding) and then after being given 8–15 g of free food (postfeeding). In both conditions, a stimulus of variable length (Millenson & Hendry, 1967) ended with an unavoidable shock. The panel on the left in Figure 8 shows that mean rates of responding in the safe periods (i.e., in the absence of the preshock stimulus) were consistently higher in the prefeeding condition that in the postfeeding condition. The preshock stimulus suppressed both these patterns of behavior, the effect being dependent on the intensity of the shock delivered in the various phases of the experiment. The absolute decrease in response rate was greater in the prefeeding condition. However, the panel on the right in Figure 8 shows that in terms of a suppression ratio (CS/Control rate), the postfeeding condition appears to show the greater relative suppression at all shock intensities, the effect being clearer at .2 and .1 mA, where it is less contaminated by a ceiling effect produced by severe disruption of behavior. The data of this study are presented in terms of both absolute and relative response rates, and it can therefore be seen that the *lower* control response rates (postfeeding) are the *more* suppressed in terms of suppression ratios. Since, with pacing procedures in which the deprivation conditions are held constant, lower rates of responding are the *less* disrupted (Blackman, 1968b), it seems reasonable to conclude with Millenson and de Villiers that the suppressive effects of their preshock stimulus are related directly to the value of the reinforcers. Thus "emotion" has a greater disruptive effect on behavior which is less strongly motivated.
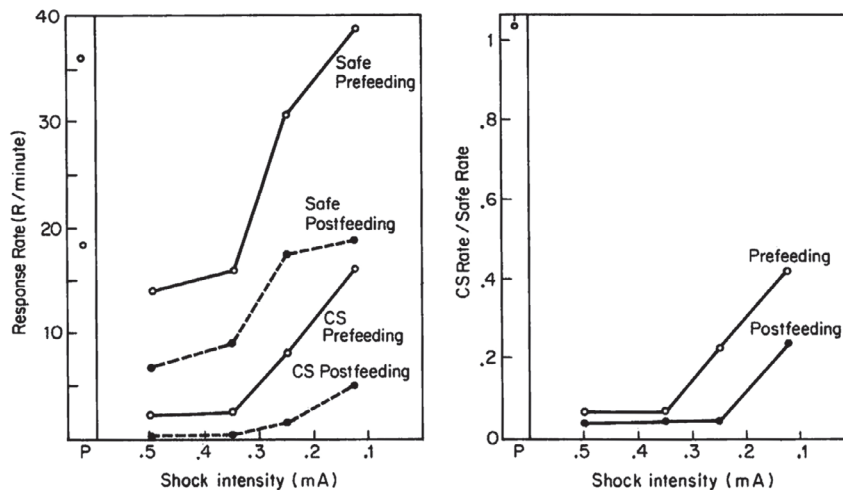

Fig. 8. The effects of a preshock stimulus on random-interval behavior in rats. The rats were tested when 9 hr food-deprived (prefeeding) and shortly after 8–15 g of free food (postfeeding). On the left are shown response rates during the CS and in its absence (safe) in both conditions. On the right are shown the resulting suppression ratios. (From Millenson & de Villiers, 1972.)

Millenson and de Villiers (1972) also reported an interesting change in relative preference when a pre-shock stimulus is superimposed on behaviors which are maintained by a concurrent schedule of reinforcement. Rats were exposed to a situation in which they could always press one lever for occasional access to 1.5-sec milk reinforcement or press another lever for access to the same reinforcer for 4.5 sec. In control conditions, an asymmetric performance was observed, rats showing some preference for the second lever. During a preshock stimulus which was superimposed on this concurrent schedule, the preference was enhanced, there being more suppression (in relative terms) of the responding on the 1.5-sec lever than on the 4.5-sec lever. This is further support (it is argued) for a drive decrement theory of conditioned suppression, since the increase in preference results from the greater suppressive effect of a conditioned emotional response on the less motivated behavior.

Motivational theories suggest research which might not arise from other conceptual schemes. Empirical data such as those of Millenson and de Villiers are therefore welcome and challenging. However, as with all such theories, there are potential disadvantages in the motivational view of conditioned suppression with its appeal to states which cannot be measured directly. For example, the differential effects of a pre-shock stimulus on behavior maintained by various schedules (discussed in the section on operant conditioning parameters, above) may too easily be translated into motivational terms in a way which can be difficult to refute. If a pattern of behavior proves to be susceptible to conditioned suppression, this can be taken as evidence that motivation is weak. On the other hand, behavior which is resistant to conditioned suppression can readily be described as strongly motivated. Since behavior which is reinforced frequently is less disrupted by a preshock stimulus, motivation can be said to vary with reinforcement frequency in a way that seems acceptable. Similarly, animals can be described as weakly motivated in the postreinforcement pause on a fixed-ratio schedule, thus handling Lyon's (1964) conditioned suppression data discussed earlier. But it has also been argued (Millenson & de Villiers, 1972) that because high rates of responding are relatively susceptible to conditioned suppression, they may be weakly motivated. This view may seem initially less plausible. It is true that Fantino (1968) has shown that animals prefer situations in which they are allowed to obtain reinforcement by responding at unpaced rates to situations in which they are required to respond at high rates. This might appear to be the independent evidence of the strength of

motivation generated by different schedules which is clearly required to support the motivational theory of conditioned suppression. However, on this basis Fantino's experiment does not suggest a reason why low rates of responding are even more resistant to conditioned suppression than unpaced moderate rates, since he found that the latter are preferred in choice situations.

The idea that conditioned suppression results from an underlying emotional state has proved attractive in psychopharmacology. It has been argued that this behavioral manifestation of anxiety or of a conditioned emotional response may prove useful in the analysis of drugs which are presumed to act specifically on such states. Hence the effects on conditioned suppression have been reported of many drugs such as "tranquilizers" and barbiturates which have been used in clinical practice in an attempt to alleviate anxiety states. These reports have recently been reviewed by Millenson and Leslie (1974), who point out the considerable advantages of the conditioned suppression procedure in this context. First, as is the case with most operant conditioning experiments, experimental sessions may continue for long periods, thereby allowing the time course of a drug's effects to be measured. (See also Thompson & Boren, Chapter 18 of this volume.) Second, by choosing the parameters of the conditioned suppression experiment judiciously, it is possible to establish partial suppression during a preshock stimulus, thereby providing a behavioral base line which is sensitive to either alleviating or enhancing effects of a drug on anxiety. Third, and perhaps most important, since the procedure includes both signaled periods when anxiety is presumed to be suppressing behavior and periods of safety from aversive stimuli, it is possible to provide a within-sessions control for any side effects which a drug might have on overall motivation, on sensory function, or on locomotor activity.

An early experiment by Brady (1956) has been widely cited as illustrating the potential of this technique. Brady, using rats as subjects, established partial conditioned suppression of intermittently reinforced operant behavior during a preshock stimulus and then investigated the effects of amphetamine and of reserpine. Brady claimed that both these drugs had specific effects "in the affective sphere," i.e., on the conditioned emotional response. Thus amphetamine strengthened the CER, for in comparison with saline conditions the drug produced a decrease in the number of responses emitted during the preshock stimulus, in spite of what Brady described as a nonspecific side effect on the behavioral base line taking the form

of an overall *increase* in control response rates. Simi-larly, it was argued that reserpine attenuated the CER: despite a nonspecific decrease in overall re-sponse rate, the number of responses during the pre-shock stimulus was greater than on saline days.

Unfortunately, subsequent work in this area has not consistently produced similarly encouraging data, and some signs of gloom have emerged as to the gen-eral usefulness of conditioned suppression as a model of anxiety in this context (e.g., Davis, 1968; Kelleher & Morse, 1964). Failures to produce clear-cut effects have led to interestingly different interpretations on occasion. Thus Kinnard, Aceto, and Buckley (1962) were led to conclude that conditioned suppression is not a model of anxiety. On the other hand, Ray (1964) concluded from essentially similar results that it *is* a model of anxiety, and that therefore "tranquilizing" drugs do not have a specific effect on anxiety.

It seems likely that the conditioned suppression phenomenon is a simple model of anxiety only on a superficial level. We have seen some of its complex-ities in preceding sections, and these must surely com-plicate the analysis of any drug's effects. Thus Appel (1963) has shown that a dosage of reserpine which reli-ably reduced conditioned suppression when the shock intensity was .8 mA failed to produce consistent effects when the shock was increased only to 1.0 mA. Simi-larly, the response rates during the preshock stimulus in Brady's (1956) experiment may have been changed not only by any specific effect of the drugs on the CER but also by the "nonspecific" side effects of the drugs: for example, the increased overall response rates pro-duced by amphetamine may themselves have pro-duced the relative decrease in response rates during the preshock stimulus (Blackman, 1972). Or again, since amphetamine is known to be an anorexic agent, the relative susceptibility of behavior to suppression after its administration may be the result of a rela-tively low motivational state in the subject on those days (Millenson & Leslie, 1974). Finally, any attenuat-ing or enhancing effects of a drug on the amount of conditioned suppression may merely be the outcome of a drug's rate-dependent effects on the two rates of responding during and in the absence of the preshock stimulus (Wuttke & Kelleher, 1970).

Despite the complexities of the situation, Millen-son and Leslie (1974) have suggested that the effects of drugs on conditioned suppression have not been as inconsistent as has sometimes been supposed. They consider the reported effects of chronic and acute doses of various drugs separately and conclude that minor tranquilizers (benzodiazepines, barbiturates, and me-probamate) have a relatively consistent effect in allevi-ating suppression in acute doses; on the other hand, it seems that phenothiazines and reserpine alleviate suppression fairly consistently in studies in which they are administered chronically.

The final experiment to be considered in this short review of drug effects was reported by Miczek (1973) and suggests that an emotional substrate of condi-tioned suppression may indeed be specifically affected by some drugs. Miczek reports that chlordiazepoxide alleviates conditioned suppression of behavior main-tained by a VI schedule. His report presents data (shown on the right in Figure 9) in terms both of suppression ratios and of base line response rates fol-lowing various injections of the drug, and in this case it seems that the dose-related alleviation of con-ditioned suppression is not contaminated in any gross way by any changes in behavioral base lines. Even more important evidence, however, is to be found in the effects of the drug administered to other animals exposed to a slightly different situation. These rats were also trained on a VI schedule. In their case, however, a stimulus was superimposed which ended
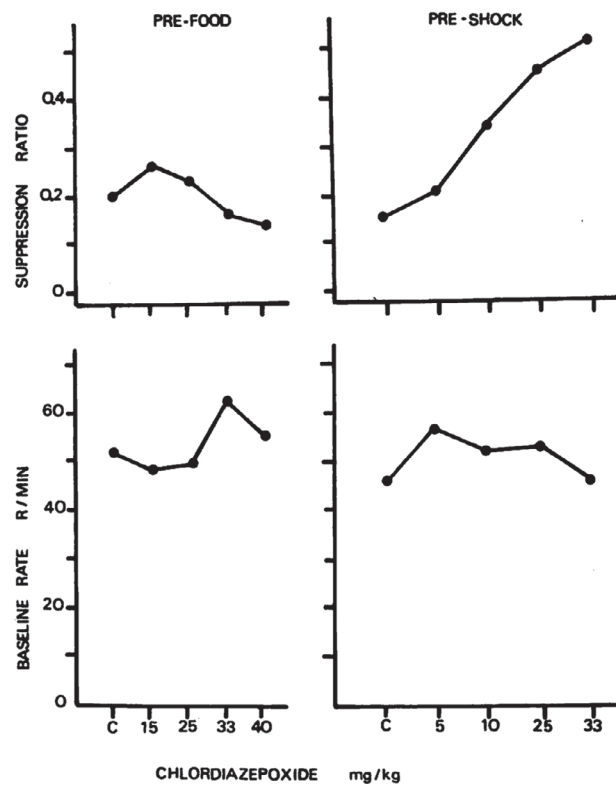

Fig. 9. The effects of chlordiazepoxide on suppression during a stimulus which precedes food (left) or shock (right). Suppression ratios are shown at the top and base line response rates below. Notice that the schedules of dosages are not identical in the two conditions. (Redrawn from Miczek, 1973.)

not with a shock but with the delivery of free food. Operant behavior was suppressed during this stimulus in much the same way as occurs during a preshock stimulus (this finding of "positive conditioned suppression" is reviewed in the next section of this chapter). Miczek reports, however, that this suppression of operant behavior was not attenuated by injections of chlordiazepoxide (see the left panels in Figure 9). These results suggest the drug has a specific effect on anxiety, rather than simply exerting different effects on different rates of responding regardless of the nature of the US signaled by the CS.

Studies of drug effects on conditioned suppression usually attempt to identify specific effects on the emotional states which are thought to produce the suppression. It may be recognized that these rather vaguely defined emotional states may be regarded as conditioned responses and might therefore have been discussed in the context of the interference hypothesis—i.e., emotion (anxiety) is a classically conditioned response which disrupts ongoing operant behavior. However, most drug studies do not attempt to identify the interfering conditioned emotional response per se, and that is why they have here been discussed in the context of a motivational theory.

The Punishment Hypothesis

In the conditioned suppression procedure a stimulus is superimposed on ongoing behavior and ends with a shock which is delivered regardless of what the subject does. *Punishment*, however, is defined as the "reduction of the future probability of a specific response as a result of the *immediate* delivery of a stimulus" (such as a shock) after that response (Azrin & Holz, 1966, emphasis added). It has been suggested that there are no fundamental differences between the processes that lead to these two forms of suppression. On the one hand, it has been argued (e.g., by Estes, 1944) that responding which is explicitly followed by shock is suppressed by the process outlined above in the motivational theory of conditioned suppression. Thus the shock is associated with certain external cues: these become conditioned stimuli by a Pavlovian procedure, and so behavior is suppressed as a result of a conditioned emotional response. This account has few advocates today as a theory of punishment (Azrin & Holz, 1966). However, the opposite theory has also been presented—that conditioned suppression results from an occasional chance contiguity between operant behavior and the delivery of a shock. This theory has been discussed at some length by Lyon (1968), and since there have been relatively few recent

experiments explicitly designed to test it, will be dealt with only briefly here.

Clearly, shocks delivered "independently" of behavior may occasionally be associated with behavior in this way. Gottwald (1967) has shown that the amount of conditioned suppression on any trial is affected by the proximity of shock to a response on the previous trial. However, there are a number of reasons to doubt that conditioned suppression is principally caused by adventitious punishment. One of the most important of these is represented in Rescorla's work reviewed earlier. In his experiments, the association of a stimulus with shock is accomplished "off the base line," i.e., before operant training is begun. Subsequently only the conditioned stimulus is superimposed on operant behavior, and there is therefore no opportunity for any adventitious contiguity between shock and response. Yet, of course, conditioned suppression does occur during the CS in these experiments. Hoffman and Barrett (1971), using observational techniques and initial association of a stimulus with shock "off the base line," have also failed to support the punishment hypothesis with pigeon subjects, since again conditioned suppression developed when possible contiguity between shock and responding was minimized. There is also a good deal of evidence that the development of conditioned suppression may be accompanied at a gross level by more signs of autonomic disturbance than is punished behavior (Hunt & Brady, 1955). In addition, Annau and Kamin (1961) have claimed that a shock of .28 mA was sufficient in their experiment to suppress behavior when used in a punishment procedure, but not when used in the conditioned suppression procedure. Orme-Johnson and Yarczower (1974) used a yoking procedure, in which pigeons were exposed either to a discriminated punishment procedure or to one which delivered the same number of shocks independently of behavior. They reported that the latter procedure produced suppression while the former produced none. Moreover, the stimulus associated with shock in the conditioned suppression procedure acquired conditioned punishing effects, while the discriminative stimulus for the punishment procedure did not.

Lyon (1968) has argued that "punishment and conditioned suppression do not represent a behavioral dichotomy but specific points on a behavioral continuum," a suggestion that it is difficult to refute unequivocally. Differences between the effects of the two procedures may always be interpreted in such a way. However, considerable procedural differences between punishment and conditioned suppression inevitably present difficulties in comparing them, not

least because suppression of responding has a conse-
quence in reducing shock frequency in the former
case but not the latter. It therefore seems unrewarding
to try to reduce either one to the other, and this is
perhaps why there is little current research with this
emphasis.

A BRIEF REVIEW OF SOME OTHER
CLASSICAL-OPERANT INTERACTIONS

The problems and questions arising from the study
of interactions between classical and operant condi-
tioning have been illustrated so far exclusively by
studies in which stimuli associated with shock have
been superimposed on operant behavior maintained
by food or water reinforcement. We now turn to con-
sider briefly some other procedures.

For some time, motivational theories of condi-
tioned suppression gained considerable support from
their apparent ability to handle data describing the
effects of signaling an unavoidable shock when an
animal's operant behavior is maintained by a schedule
of shock avoidance. For example, Rescorla and Solo-
mon (1967) have argued that the laws of Pavlovian
conditioning are "the laws of emotional'conditioning
or laws of acquired drive states" and that "condi-
tioned emotional states change [the subject's] motiva-
tion level and thus can serve either as motivators or
reinforcers of instrumental responses." They there-
fore make the general assertion that aversively moti-
vated operant behavior will increase in frequency dur-
ing a stimulus which precedes an unavoidable shock,
since this conditioned emotional state will summate
with the motivation maintaining avoidance behavior.
Studies by Sidman, Herrnstein, and Conrad (1957),
Kelleher, Riddle, and Cook (1963), and Waller and
Waller (1963) all showed that free operant avoidance
did increase in frequency in this way during a stim-
ulus which preceded the delivery of an unavoidable
shock. However, more recently there has been a num-
ber of reports of conditioned suppression even of
avoidance behavior (e.g., Blackman, 1970b; Bryant,
1972; Hurwitz & Roberts, 1969; Pomerleau, 1970;
Roberts & Hurwitz, 1970; Scobie, 1972). It seems that
suppression of avoidance behavior may occur if the
unavoidable shock is discriminable from avoidable
shocks (e.g., of a different intensity), or if such sup-
pression does not increase the overall frequency of
shocks, either because the avoidance schedule is sus-
pended during the warning signal or because the re-
sponse-shock times of the schedule are relatively long
in comparison with the duration of the signal. At

present, it is not easy to predict precisely the circum-
stances in which suppression will be the rule, but it is
difficult to fit examples such as these into any tradi-
tional motivational theory. On the other hand, an
interference hypothesis should in principle be as ca-
pable of handling suppression of avoidance behavior as
of coping with suppression of positively motivated be-
havior. The problem with this theory, however, is that
it offers little in the explanation of any *acceleration* of
avoidance behavior during a conditioned stimulus.

Rescorla and Solomon (1967) also predicted on the
basis of their motivational theory that, in their terms,
any appetitively motivated behavioral base line will
increase in frequency during an appetitive Pavlovian
conditioned stimulus. In other words, food-reinforced
operant behavior should increase in frequency during
a signal that ends with presentation of free food. We
have seen already, however (Miczek, 1973), that condi-
tioned *suppression* may occur during such a stimulus.
For example, using rats as subjects Azrin and Hake
(1969), Meltzer and Brahlek (1970), and Hake and
Powell (1970) have all reported suppression of re-
sponding during a stimulus lasting 10 or 12 sec and
ending with the presentation of free food. Similarly,
suppression has been reported with monkeys during
prefood stimuli (Kelly, 1973a, 1973b; Miczek & Gross-
man, 1971). It is difficult to see how the Rescorla and
Solomon (1967) account of classical-operant interac-
tions can handle such findings. It is intriguing, how-
ever, to see the vigor with which other theoretical
accounts of the more traditional conditioned suppres-
sion during a preshock stimulus have been extended
to this so-called positive conditioned suppression. In
their study, Azrin and Hake (1969) used either food or
water as the reinforcer for operant behavior and de-
livered "free" food, water, or intracranial stimulation
at the end of their stimulus. In general, they found
suppression during the stimulus with all the combina-
tions of reinforcer and US which they tested. They
suggested that such suppression was the result of a
"general emotional state" and argued that suppression
during a pre*shock* stimulus is another example of the
effects of such a state, rather than a model of a specific
anxiety state. Azrin and Hake do not specify the
nature of this general emotional state, but it would
seem to be basically similar to Skinner's concept of
emotion (1938, p. 407).

Kelly (1973a) has attempted to monitor any
changes in autonomic activity in monkeys which
might be conditioned during a prefood stimulus, with
a view to evaluating the interfering respondents
hypothesis in the context of positive conditioned sup-
pression. Using the same experimental techniques to

monitor cardiovascular activity as Brady, Kelly, and Plumlee (1969) had employed in their study of pre-shock stimuli, Kelly was again unable to detect any systematic covariation of changes in autonomic activity and operant suppression. He therefore dismisses the idea that positive conditioned suppression is caused by interfering respondents produced by the Pavlovian aspects of the procedure.

One difficulty in considering a theory of positive conditioned suppression in terms of interfering respondents is that the status of the free food as a Pavlovian unconditioned stimulus is by no means clear. In all the studies in this area, except when brain stimulation ended a stimulus in Azrin and Hake's (1969) study, the delivery of the "free" event seems to act more as a discriminative stimulus setting the occasion for an approach response to a particular part of the experimental chamber than as a stimulus which unconditionally elicits some response. This observation serves to emphasize the possibility that positive conditioned suppression might be produced by interfering *operants,* a recurring theme in this research (Farthing, 1971). Thus it may be that recorded operant responding decreases because the subject makes preparatory approaches to the food cup which maximize the speed of taking up the free food when it is delivered, although most reports in this area claim that such behaviors could not be detected. Also, whether suppression or acceleration of responding develops during a prefood stimulus, the possibility must be considered that this is superstitiously reinforced by the delivery of the free food—an analogue of the punishment hypothesis of the effects of preshock stimuli. However, the evidence for superstitious reinforcement in this context is not strong (see Staddon, 1972).

The effects of prefood stimuli are being shown increasingly to depend on the parameters of the situation and on the nature of the behavior on which they are superimposed. Thus Meltzer and Brahlek (1970) reported acceleration of rats' variable-interval behavior during a 120-sec prefood stimulus, but, as noted, suppression during a 12-sec stimulus. Henton and Brady (1970) trained monkeys on a DRL 30-sec schedule and found no effect of a prefood stimulus of 20 or 40 sec, but they found *acceleration* during a prefood stimulus lasting 80 sec. Kelly (1973b) also found acceleration of monkeys' DRL behavior during a 60-sec prefood stimulus; his experiment, however, also made it possible to compare this effect with that of the same prefood stimulus on random ratio behavior. This revealed a schedule-dependent effect, for the latter behavior was suppressed during the stimulus.

Smith (1974), using pigeons, investigated the contribution of various response rates and reinforcement frequencies to the effects of prefood stimuli of various lengths. He found that both high and low response rates were *increased* during a 5-sec prefood stimulus. With longer stimuli, high rates were suppressed, but low response rates were unaffected. With two of the three subjects, high response rates were less suppressed when they obtained high frequencies of reinforcement rather than lower frequencies. It is clear from this study that there are considerable similarities in the variables which control the amount of suppression during a prefood stimulus, as here, and during a preshock stimulus (e.g., Blackman, 1968b).

There appears to be an important species-dependent effect when relatively short prefood stimuli are used in experiments. Although the above review suggests that the behavior of rats and monkeys is consistently suppressed in such conditions, LoLordo (1971) has found that pigeons' response rates increase. Similarly, Smith (1974) found increases in various behavioral base lines during a 5-sec prefood stimulus with his pigeons. In a recent study, LoLordo, McMillan, and Riley (1974) have thrown considerable light on this anomaly. They found that if the operant response being studied was key pecking, response rates increased if the prefood stimulus was a change in the illumination of the key. However, if the prefood stimulus was a nonlocalized tone, there was no acceleration. Similarly, there were no consistent effects of a tone or light prefood stimulus if the operant was treadle pressing rather than key pecking. The authors interpret these results as suggesting that the accelerative effect dependent on a localized prefood stimulus is an example of an autoshaped and automaintained response (Brown & Jenkins, 1968). This suggestion has the immediate effect of bringing the discussion toward the work of Gamzu and Schwartz (1973), who have developed the view that key-pecking rates of pigeons may depend on a summation of pecking maintained by instrumental contingencies per se and pecking which is supported by automaintenance. Since auto-shaping and automaintenance have been discussed in the context of classical rather than operant conditioning (Jenkins & Moore, 1973), the work of Gamzu and Schwartz (1973) and its extension to phenomena such as behavioral contrast (e.g., Keller, 1974) is clearly relevant to the study of interactions between classical and operant conditioning. However, since they are discussed elsewhere (Chapter 3), these ideas are not developed here.

It can be seen then that there has been much recent work on the effects of prefood stimuli on operant be-

havior. Some studies have even reported that such stimuli may have suppressive effects on behavior maintained by an avoidance schedule (e.g., Davis & Kreuter, 1972; Henton, 1972). In general terms, studies of the effects of prefood stimuli have developed in a similar way to those of preshock stimuli. In both cases, the parameters of the procedure and the nature of the behavioral base lines on which it is superimposed are crucial, and this makes it impossible to make general assertions that a given preevent stimulus will have simply suppressive or enhancing effects on behavior. There is at present no adequate general theory, whether this be couched in terms of a general emotional state, conditioned drives, competing respondents or operants, or superstitious reinforcement of different rates by the delivery of free food. In short, research in this area may be said to mirror almost exactly the problems which have been discussed in the context of preshock stimuli throughout this chapter.

CONCLUSION

The procedures we have considered in this chapter have an apparent simplicity that can obscure the very real complexities both of measurement and of interpretation. In particular, the appropriate measurement of the disruption of operant behavior by classical conditioning procedures poses great problems. There is a real danger that describing these effects in terms of a relative rate during the conditioned stimulus can obscure important aspects of the situation. In spite of this, we have seen that the measurement of Pavlovian conditioning processes through what is usually regarded as their indirect effects on operant behavior has been widely recognized as being unusually sensitive and thereby productive. On the other hand, attempts to monitor any autonomic effects which might be supposed to be *directly* conditioned by the Pavlovian aspects of the procedure have been generally disappointing: autonomic changes often do occur during the conditioned stimulus, but they in no sense appear to reflect the orderliness of the indirect operant effects which one might suppose to be mediated by the classical conditioning of autonomic processes. Faced with this problem, it has been argued that it is a rather ill-specified conditioned emotional response (CER) which is the direct outcome of the Pavlovian aspects of the conditioning procedure. Some workers have preferred to describe this CER as conditioned anxiety, a term which has a degree of superficial validity in a situation in which a stimulus precedes an unavoidable aversive event. However, more recently the idea of a general emotional state has been revived, of which the traditional conditioned emotional response is said to be but one example. A further theory suggests that disruptive effects of a conditioned stimulus result from the conditioning of a motivational state which interacts with the motivation which supports the base line operant behavior. Yet a further possibility is that disruption of operant behavior during a preevent stimulus is the outcome of poorly controlled instrumental contingencies and hence reflects the strength of other interfering operants or the result of adventitious punishment or reinforcement.

Whether disruptions of operant behavior are thought to reflect underlying classical or operant conditioning effects or the development of changed motivational states, it is quite clear that the effects of any preevent stimulus depend critically on the nature of the behavioral base lines on which they are superimposed. The effects of classical conditioning procedures on operant behavior are therefore schedule-dependent, as are the effects of so many other independent variables. The differing degrees of susceptibility to disruption by a Pavlovian conditioned stimulus pose further questions: do these differences reflect different strengths of an underlying conditioned response, or is this strength determined solely by CS–US parameters so that different degrees of suppression reflect the resistance to disruption of different patterns of operant behavior? Similar problems of interpretation arise from the effects of drugs on disruptions of operant behavior during a conditioned stimulus and clearly return us to the problem of appropriate measurement.

In spite of the many problems of measurement and interpretation which have been discussed in this chapter, studies of the effects of classical conditioning procedures on operant behavior have long played an honorable role in learning theory. A problem in reviewing this research, however selectively, is that it has been related at various times to many theoretical controversies in psychology, and these general issues have been mentioned only briefly here. The procedure has proved to be successful in providing a sensitive dependent variable for the study of the necessary and sufficient conditions for the development of an acquired reflex. However, research using this procedure has also provided empirical evidence which has been related to motivational theories of behavior and the role of classical conditioning in motivation, to the study of emotion, to the relations between physiological events and overt behavior, to the study of the effects of potential anxiolytic agents, and to many other important problems. Indeed, perhaps one of the

most important features of these studies is that they provide a focus for discussion between workers of different theoretical persuasions. In this light, it seems almost symbolic that the amount of conditioned suppression in a specified situation is a function of both classical and operant conditioning parameters, and that this disruption seems at present not to be a direct reflection of underlying physiological or autonomic processes. This complexity emphasizes that no one approach to the problems discussed here can be thought of as dominant. Hearst and Jenkins (1975) have recently suggested that identifying the different forms of learned behavior which develop in specified circumstances is at present preferable to the espousal of any universal theory of learning. The results reviewed in this chapter support this view.

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