JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1972, 17, 277-285 NUMBER 2 (MARCH)

CONDITIONED SUPPRESSION OF AN AVOIDANCE RESPONSE BY A STIMULUS PAIRED WITH FOOD[1]

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Three food-deprived Long-Evans rats were exposed to a non-discriminated shock avoidance procedure. Superimposed upon this operant avoidance baseline were periodic presentations of a conditioned stimulus that was paired with food, the unconditioned stimulus. These pairings resulted in increases in the rate of shock over that recorded when the conditioned stimulus was not present. A traditional suppression ratio failed to reveal any differential effect of the conditioned stimulus on the overall rate of avoidance responding, although all subjects showed a consistent pattern of pausing and postshock response bursts during presentations of the conditioned stimulus. When food was withheld during a final extinction phase, the conditioned stimulus ceased to occasion increases in shock rates and disruptive postshock response bursts were eliminated. An analysis of conditioned suppression procedures is proposed that stresses not only operant-Pavlovian or appetitive-aversive incompatibility, but also the manner in which the baseline schedule of reinforcement affects operant behavior changes that are elicited by the superimposed Pavlovian procedure.

There are only four possible experimental arrangements in which operant and Pavlovian conditioning involving appetitive or aversive stimuli may be combined. Probably the most common is the conditioned suppression or Estes-Skinner (1941) procedure in which a conditioned stimulus (CS) paired with an aversive unconditioned stimulus (US) is superimposed upon an appetitively maintained operant baseline. This unavoidable CS-US presentation typically produces a suppression of baseline operant responding during the CS, although a number of procedural variations have been shown to attenuate this suppression (Davis, 1968).

In addition to the Estes-Skinner procedure, a combination of operant and Pavlovian conditioning may employ aversive stimuli in both procedures; *i.e.*, an aversively-maintained operant baseline upon which a CS and aversive US is superimposed. This arrangement was investigated by Sidman, Herrnstein, and Conrad (1957) who exposed monkeys to a non-discriminated shock avoidance procedure (Sidman, 1953) during which a 5-min CS that terminated with unavoidable shock was alternated with 5-min non-CS periods. A threefold increase in response rate was noted during CS presentations. More recent studies, however, raise considerable question about the nature of such response acceleration. Hurwitz and Black (1968) superimposed an aversive Pavlovian paradigm on a shock avoidance operant procedure and found that introduction of the CS initially suppressed operant responding. They suggest that facilitation found in other studies under these conditions may have resulted from response bursts that followed unavoided shocks delivered after the initial response suppression. Roberts and Hurwitz (1970) confirmed this analysis and reported that when signalled shock is superimposed upon a temporarily suspended avoidance baseline, response rates are indeed suppressed.

In contrast to the procedure in which aversive stimuli are employed as both the operant and Pavlovian reinforcers, there have been several experiments in which appetitive stimuli served to maintain the operant baseline as well as Pavlovian conditioning. This arrangement, which is sometimes referred to as the "joy" effect or conditioned elation, was first demonstrated by Herrnstein and Morse (1957). They reported large increases in responding during the 1-min CS that was superimposed upon a schedule that differentially reinforced low (DRL) rates of response. These findings were qualified in a later study by Azrin and Hake (1969) who found that the rate of re-

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sponding on a food-maintained operant baseline could be suppressed during a CS presentation that was paired with an appetitive US. Using various combinations of food, water, or intracranial stimulation as the operant reinforcement and/or the US, they reported base rate suppression during the CS when the operant reinforcer and US were discriminably different. Azrin and Hake concluded that previously reported facilitation of food-maintained operant baselines during a positive CS-US pairing was probably due to the similarity between the operant reinforcer and Pavlovian US used in these studies, and was not simply dependent on the use of positive reinforcement.

Thus, data are available for three of the four possible procedures in which operant and Pavlovian conditioning are concurrently scheduled. Disregarding recent qualifications (Hurwitz and Black, 1968; Roberts and Hurwitz, 1970; Azrin and Hake, 1969), one overview of these data might lead to the conclusion that when the operant reinforcer and Pavlovian US are similar in "polarity", *e.g.*, are both appetitive, then operant responding will be accelerated during the CS. However, when an appetitive-aversive conflict exists between these stimuli, then responding will be suppressed. If this is the case, it is reasonable to assume that a simple reversal of the reinforcement polarities used in conditioned suppression, *i.e.*, superimposing an appetitive US upon an aversively maintained operant baseline, might still yield suppression of responding during the CS. If, however, the data of Hurwitz and Black (1968), Roberts and Hurwitz (1970), and Azrin and Hake (1969) are not disregarded, then the equivocal picture produced by these finer analyses of procedure and results makes it difficult to speculate about the outcome of such an operational reversal.

In any event, the results of this new procedure supply a missing set of data in the fourfold procedural table, and would amplify understanding of the interactions that occur between appetitive and aversive, as well as Pavlovian and operant conditioning.

METHOD

Subjects

Three naive, male, Long-Evans rats, approximately 90 days old at the start of the experiment, were maintained at 80% of their free-feeding weights throughout the experiment. They had free access to water in the home cages and were fed approximately 1 hr after each experimental session.

Apparatus

Subjects were run in a sound isolation chamber from Scientific Prototype Mfg. (SPC-300) with a 7-w, 115 v ac houselight. The chamber provided enclosure for a 19 by 16 by 26 in. (48 by 31 by 66.5 cm) rodent test cage with retractable lever (Scientific Prototype Model RL-200), requiring approximately 20 g (0.196 N) downward force, and for a pellet dispenser that delivered 45-mg Noyes pellets. An electrifiable grid floor was formed by 18 stainless steel rods.

A 4500-Hz Sonalert tone (74 dB) served as conditioned stimulus (CS). Shock stimuli were provided by a Grason-Stadler shock generator and scrambler (GS 700) that delivered shock to the walls, grid floor, and lever of the test cage.

Procedure

Pretraining was divided into three phases, in which all subjects received identical treatment unless specified.

Phase I. In Sessions 1 and 2, subjects were placed in the test cage with the food cup present and the lever retracted. Food tray approach training was accomplished with the subject receiving 100 pellets in each session. During sessions 3 to 6 the CS (tone)-US (food) pairing was introduced. The termination of each tone was immediately followed by a food pellet. The conditions given in Sessions 3 to 6 are summarized in the following Table.

Table 1

The duration of each CS and the number of CS-US pairings presented in Sessions 3 to 6 of Phase I.

Session	*US Only*	*15 Sec CS*	*5 Sec CS*	*10 Sec CS*	*30 Sec CS*
3	10	100			
4		10	90		
5			10	40	
6				10	20

Beginning in Session 7, CS duration was increased to 60 sec. The exact number and distribution of CS-US presentations for Sessions 7 to 15 were determined by a random probability generator (Lehigh Valley Electronics,

#1652) operated once per minute and set at 25%. Each session lasted 1 hr and an average of fifteen 60-sec CS-US pairings were presented. Sessions 16 and 17 lasted 90 min each with the probability generator set at 10%.

Phase II. The food cup was removed and the lever was introduced into the chamber. A continuous 0.3-mA shock was delivered to the grid floor, walls, and lever. The subject was placed in the electrified cage and was trained to barpress in order to terminate shock. Each subject required approximately 5 min of training until escape responding occurred within 2 sec of shock onset. All subjects received 2 hr of exposure to the escape schedule before the avoidance contingencies were introduced.

Subjects were trained to respond on a Sidman avoidance schedule. Shock intensities were selected individually to maximize performance for each subject and were set at 0.5, 0.6, and 0.8 mA for Subjects HA-1, HA-2, and HA-3, respectively. Maximum shock duration was set at 0.5 sec with the circuit arranged so that each barpress would terminate the shock immediately. Under the Sidman avoidance schedule, a response must occur during a fixed response-shock (RS) interval or shock is delivered at the end of the RS interval and continues to be delivered at fixed intervals (the shock-shock, SS, interval) until a response is made. The RS and SS values are given in seconds for each subject: HA-1: RS = 25, SS = 10; HA-2: RS = 30, SS = 15; HA-3: RS = 30, SS = 10. All subjects were given a minimum of twenty-eight 90-min training sessions. A criterion for stability of the avoidance baseline was established and met in the final 10 sessions. The standard deviation was less than 10% of the average number of responses made during these sessions.

Phase III. All subjects were run for four sessions. Sessions 1 and 3 lasted 90 min each and consisted of random presentation of the 60-sec CS-US (tone-food) pairings as described in Phase I. The avoidance schedule was not in effect. Sessions 2 and 4 lasted 90 min each and consisted of Sidman avoidance training as described in Phase II. No CS-US presentations were scheduled.

Phase IV. Fifteen 90-min sessions were given with the food cup present and the lever introduced. Subjects were simultaneously exposed to their respective Sidman avoidance schedules and the CS-US pairings. Presentations of CS-US pairings were controlled by a probability generator operated once per minute and set at 10%.

Phase V. Ten sessions were conducted with all conditions identical to those of Phase IV, except that all USs (food) were withheld.

Data Collection and Analysis

A CS ratio was computed for each session by dividing the response rate during CS minutes by the response rate during non-CS minutes of the session. A ratio equal to 1.00 indicates no differential effect by the CS on response rate; ratios smaller than 1.00 indicate suppression of avoidance responding during the presence of the CS; ratios larger than 1.00 reflect a higher response rate during the CS.

The number of shocks received during both the CS and non-CS minutes was recorded for each session. A shock ratio was computed by dividing the shock rate during CS minutes of the session by the shock rate during the non-CS minutes of the session. Thus, a ratio of 1.00 indicates no difference between the average number of shocks received during the CS and during non-CS minutes of the session; ratios larger than 1.00 indicate a higher shock rate during CS presentations; and shock ratios smaller than 1.00 reflect a lower shock rate during the CS. If all shocks were avoided during the CS, the shock ratio was equated to zero.

RESULTS

In general, regardless of differences in avoidance schedule parameters and shock intensity, the Phase IV effects of superimposing appetitive CS-US pairings on an aversively maintained operant baseline were consistently disruptive. Despite the fact that absolute shock rate remained virtually unaffected throughout the experiment, Phase IV increases in the rate of shock were recorded for all subjects during the CS minutes relative to non-CS shock rate (see Figures 1 and 2). Response rates during CS minutes of Phase IV, however, remained virtually unchanged from response rates recorded in non-CS minutes (see Figure 3). Individual session CS ratios upon which Figure 3 is based range from 0.92 (HA-1; Session 13) to 1.08 (HA-2; Session 6), indicating no discernable effect of the appetitive CS on the rate of avoidance responding. Failure to find disruption of avoidance response rate is further borne out in the fact that all subjects' absolute rates remained basically unchanged from the final pre-CS sessions of Phase III through the final sessions of Phase V in which food USs were withheld (see Figure 4).

The CS-US presentations did appear to affect the temporal patterning of avoidance responding, however. These effects are illustrated in Figure 5. The most reliably disruptive part of the CS on responding was its onset. Beginning with the first session in Phase IV, there was nearly always a brief period at the start of the CS during which avoidance responding remained suppressed. Exceptions to this typically involved occasions on which an unavoided shock occurred during this initial period of the CS and resulted in a "burst" of postshock responding. Such postshock response bursts were fairly typical of behavior during the CS and accounted for the increased shock rates during the CS, despite the virtual equivalence of response rates in this period to non-CS responding.

There were several instances in which responding was suppressed late in the CS immediately before US delivery. This tendency, which did not appear until the later sessions of Phase IV, was nearly always accompanied by increased activity at the feeder tray, such as gnawing and mounting. Such behaviors were not observed during the suppression associated with onset of the CS.

When the US (food) was withheld in Phase V, the disruption of avoidance efficiency was notably reduced for all subjects. Although absolute response rates and CS ratios remained

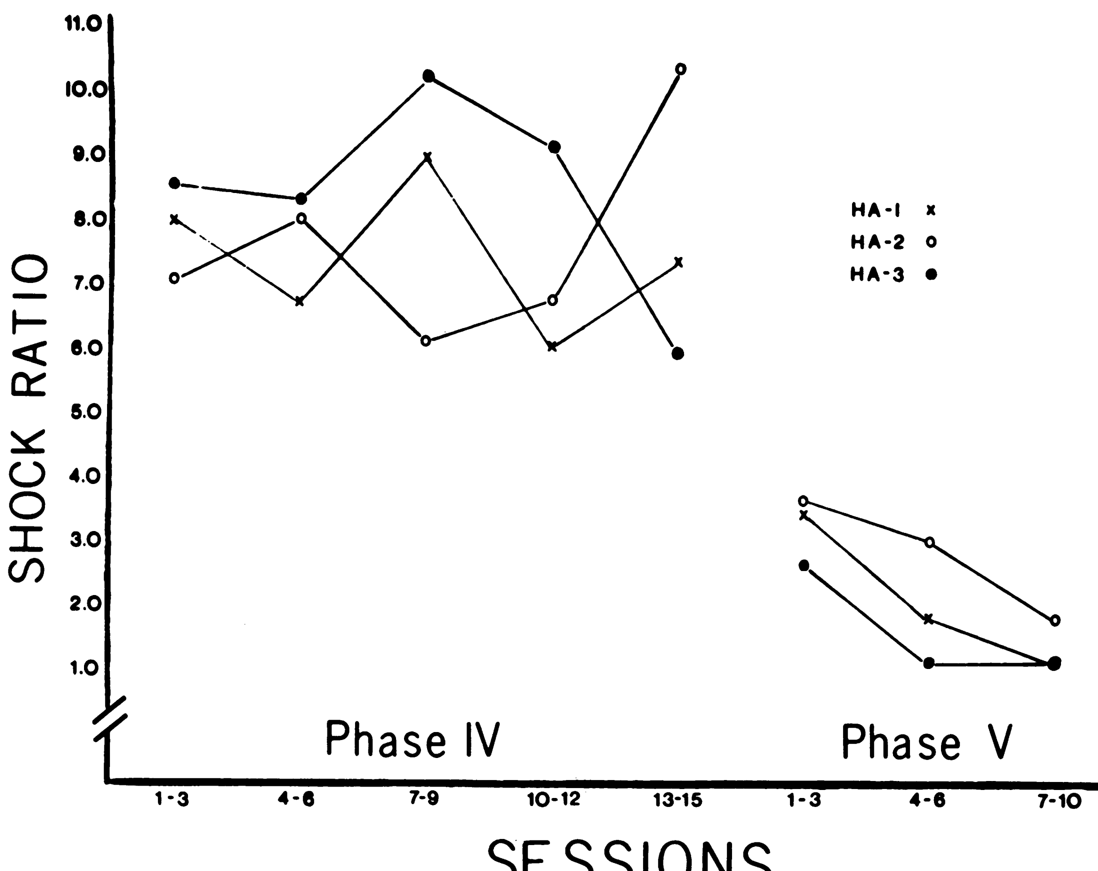

Fig. 1. Average Shock Ratios (Shock Rate in CS min/Shock Rate in non-CS min) obtained for each subject during blocks of sessions in Phase IV when each CS was paired with a food-US, and during Phase V when food-USs were withheld. Shock Ratio = 1.00 indicates equivalence between the rate of shocks taken in CS and non-CS minutes of session.

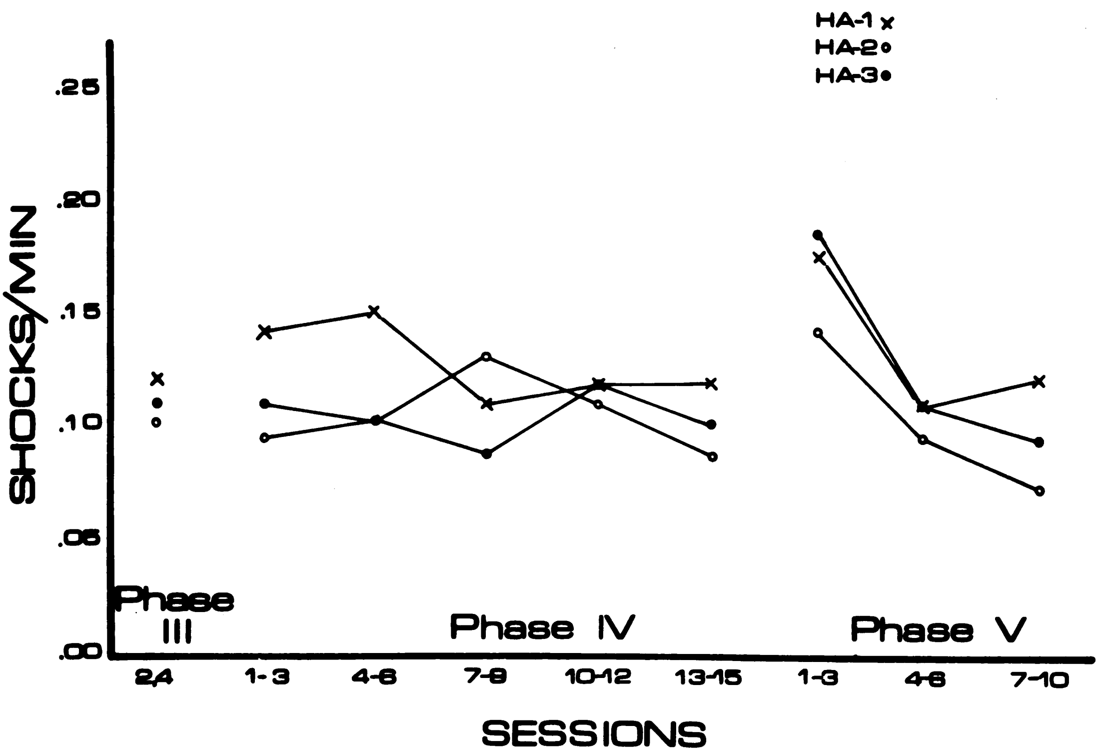

Fig. 2. Overall rate of shocks delivered per minute to Subjects HA-1, HA-2, and HA-3 during Phase III avoidance sessions before superimposed CS-US pairings; during blocks of consecutive sessions in Phase IV when CS-food US pairings were presented; and during blocks of consecutive sessions in Phase V when the food USs were withheld.

virtually unchanged from Phase IV (see Figures 3 and 4), the temporal properties of responding during CS presentations in Phase V were shifted so that fewer shocks were received and all subjects' shock ratios rapidly decreased to near 1.00 (see Figure 1). Accordingly, post shock response bursts during the CS were nearly eliminated in Phase V. Suppression of responding late in the CS appeared slightly more resistant to extinction than did the previously noted suppressive effect of CS onset; however, this effect was eliminated in all subjects by the end of the fourth session of Phase V. Avoidance performance remained stable and showed no differential effects of the CS throughout the remaining sessions of Phase V.

DISCUSSION

In the present procedure, an appetitive CS-US pairing disrupted the operant avoidance baseline on which it was superimposed. The disruption appeared not in overall response rate, as CS ratios were maintained near 1.00, but rather in the increased rate of unavoided shocks received during the CS. As Hurwitz and Roberts (1969) noted, when such increases in shock rate occur in the absence of response rate changes, the distribution of responses during the CS must be different from response distributions during non-signalled periods. This inference is supported by the observation in the present study that pausing, as well as response bursts, were common during CS presentations in Phase IV.

The disruptive effects reported in this experiment, which stem from combining appetitive Pavlovian conditioning with aversive operant conditioning, could lend support to the notion of an operant-Pavlovian incompatibility (*e.g.*, Miller and Konorski, 1937; Konorski and Wyrwicka, 1950). The data also appear relevant to the possible existence of a hierarchy between appetitively and aversively maintained behaviors or motivational states. Such an assumption involving a motivational hierarchy often underlies conditioned suppression research (*e.g.*, Hunt and Brady, 1951; Davis and McIntire, 1969) and is exemplified

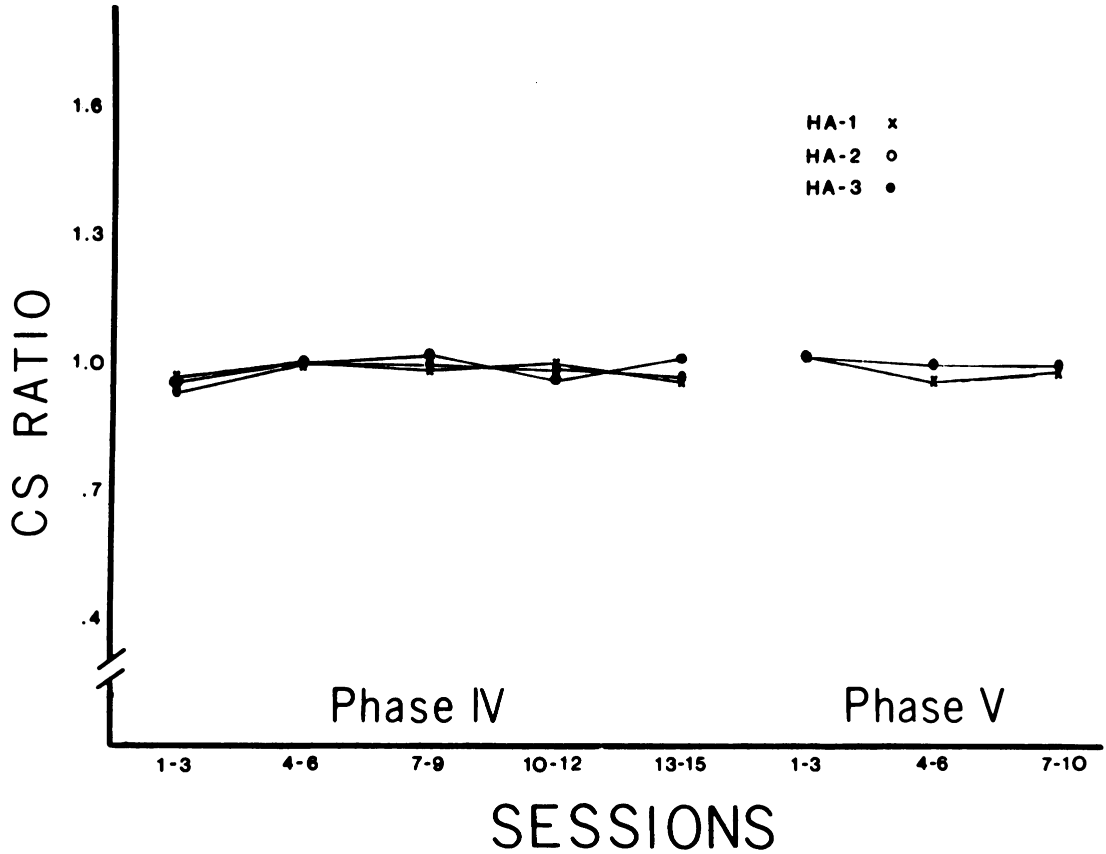

Fig. 3. Average CS Ratios (Response Rate in CS min/Response Rate in non-CS min) obtained for each subject during blocks of sessions in Phase IV when each CS was paired with a food-US, and during Phase V when food-USs were withheld. CS Ratio = 1.00 indicates equivalence between the rate of responding in CS and non-CS minutes of session.

in the formal analysis proposed by Rescorla and Solomon, 1967).

Nevertheless, it is suggested that the notion of operant-Pavlovian or appetitive-aversive incompatibility is only partially useful in accounting for the outcomes of conditioned suppression studies. For instance, despite the uniqueness of the present procedure, the nature of operant disruption obtained in this experiment is in no way unusual. In fact, the results of the present procedure are surprisingly similar to the results of an entirely different procedure (Hurwitz and Black, 1968; Hurwitz and Roberts, 1969) in which CS-shock pairings were superimposed upon an avoidance baseline. In that experiment, as in the present one, response rates remained minimally affected while shock rates were markedly increased during the CS. In another instance in which unlike procedures yielded similar results, Azrin and Hake (1969) were able to demonstrate suppression of appetitive responding, traditionally produced by an aversive CS-US, when appetitive CS-US pairings were presented during an appetitive operant baseline.

The fact that such fundamentally different procedures have yielded similar results, coupled with the previously noted inconsistent results obtained within any given procedural variation of conditioned suppression (*e.g.*, Davis, 1968; Azrin and Hake, 1969; Roberts and Hurwitz, 1970), makes one question whether the relatively simple "incompatibility" explanations tell the whole story. Specifically, if operant and Pavlovian conditioning or appetitive and aversive states are incompatible, *per se*, then why does not conditioned suppression remain invariant despite changes in schedule parameters (*e.g.*, Lyon, 1963) or in

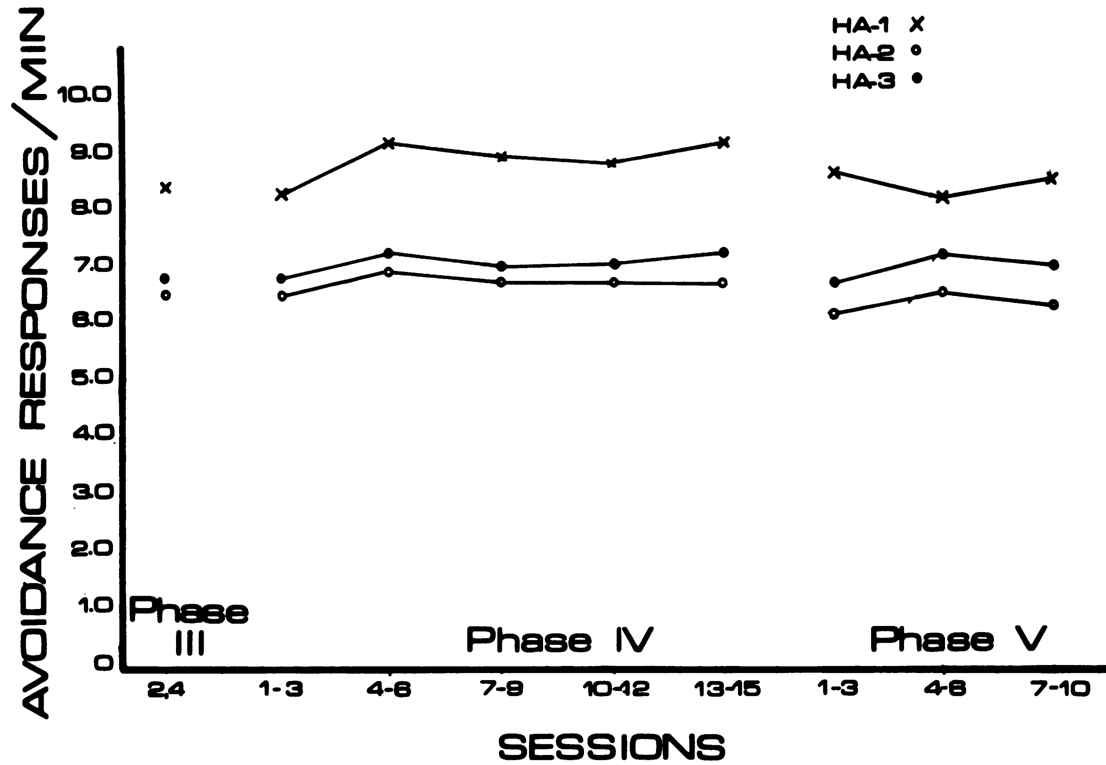

Fig. 4. Avoidance responses made per minute by Subjects HA-1, HA-2, and HA-3 during Phase III sessions before superimposed CS-US pairings; during blocks of consecutive sessions in Phase IV when CS-food US pairings were presented; and during blocks of consecutive sessions in Phase V when food USs were withheld.

the choice of appetitive reinforcers (*e.g.*, Azrin and Hake, 1969)?

Perhaps the answer lies in the fact that such theoretical explanations have failed to stress the actual reinforcement contingencies that are involved in the procedures. That is, when one emphasizes the fact that a baseline is appetitive (as opposed to aversive) or involves operant (as opposed to Pavlovian) conditioning, it is possible to lose sight of the specific contingencies that define the baseline schedule of reinforcement. Kelleher and Morse (1964) made a similar argument regarding psychopharmacology. They pointed out that in determining the effects of a particular drug on behavior, it may be of greater importance to know about the properties of the baseline schedule and the behavior it generates than to know whether the schedule has been motivationally classified as appetitive or aversive.

With this strategy in mind, the following analysis is proposed. Pavlovian conditioning, when superimposed upon an operant baseline, will initially elicit some response. Whether this response is best classified in terms of incompatible behaviors, incompatible motivational states, or what Azrin and Hake (1969) termed a "general emotional state", is not the central issue. Rather, what is crucial to an analysis of conditioned suppression is determining the manner in which the reinforcing contingencies of the baseline schedule will affect the changes in operant rate that have been elicited by the Pavlovian procedure.

For instance, if the Pavlovian CS initially results in pausing, and the operant baseline is maintained on a variable-interval schedule, such pausing is likely to be differentially reinforced, because response rates on variable-internal schedules are usually in excess of what is required for reinforcement, and a response following a pause typically has an increased probability of being reinforced (*c.f.*, Stein, Sidman, and Brady, 1958; Lyon, 1963). In contrast, if the baseline were maintained on a variable-ratio schedule, then such pausing would not be reinforced and conditioned suppression would logically be attenuated (*c.f.* Lyon and

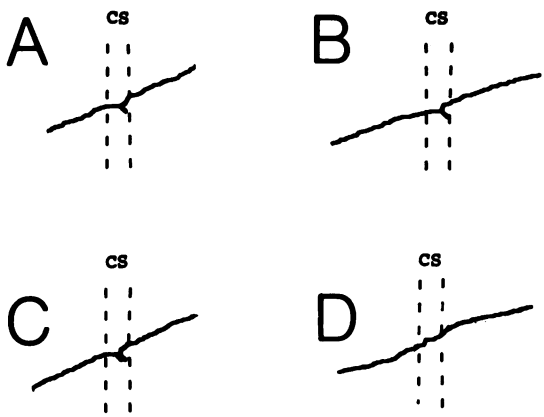

Fig. 5. Selected portions of cumulative response records illustrating changes in pattern of avoidance responding during presentation of CS. Records A and B, obtained for Subjects HA-2 and HA-1 respectively, illustrate typical pausing early in CS followed by shock delivery and response burst. Such alternating pausing and "bursts" allowed overall response rate measures to remain unaffected despite increase in shock rate during CS. Record C indicates similar pause and burst pattern in Subject HA-3, although two shocks were delivered during the CS. Record D indicates disruption of temporal pattern of responding in Subject HA-1, although pauses were not long enough to result in shock. Note response burst following initial pauses despite absence of shock.

Felton, 1966). When the operant baseline is maintained by a Sidman avoidance schedule, it would be reasonable to expect a cyclic relationship during the CS between pausing, delivery of unavoided shock, and a postshock response burst. This relationship would maintain response rates while accelerating shock rates in the same period; moreover, it would not matter if the pausing had been generated by a CS paired with food or with shock (*c.f.*, Hurwitz and Black, 1968; results of the present study). Should this cyclic relationship be interrupted by removal of the shock avoidance schedule during CS presentations, then response rates would be expected to decrease and greater conditioned suppression would result (*c.f.*, Roberts and Hurwitz, 1970).

The manner in which the Estes-Skinner procedure is discussed is, to some extent, symbolized by the two labels that are interchangeably used to describe the area: *conditioned emotional response* stresses the presumed underlying state, which has been classically conditioned and which interferes, via some hierarchy, with the measured operant. *Conditioned suppression,* on the other hand, points only to an observable change in the rate of an operant and makes no statement, other than an operational one, about the nature of a conflicting process. It is suggested that this latter approach, which leads logically to identifying the empirical properties of the procedures, is the more essential if we are to understand the dynamics of conditioned suppression.

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Received 1 March 1971.
(Final acceptance 22 September 1971.)