CONDITIONED ACCELERATION AND CONDITIONED SUPPRESSION IN PIGEONS[1]

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Two experiments were performed to investigate the effects on pigeons' keypecking behavior of stimuli that signal different kinds of aversive events: time-out from positive reinforcement, electric shock, loud noise, and loud tone. Behavior maintained by a variable-interval schedule of reinforcement was suppressed by a stimulus before shock, was accelerated by a stimulus before time-out from positive reinforcement, and was unchanged by a stimulus before loud noise or a stimulus before loud tone. Conditioned acceleration with time-out from positive reinforcement and conditioned suppression with shock were obtained regardless of whether a response contingent or response-independent procedure was employed.

A stimulus is defined as aversive if subjects will avoid it, escape from it, or if it will suppress behavior that produces it. The conditioned suppression phenomenon (Estes and Skinner, 1941) is another characteristic of at least one type of aversive stimulus, electric shock. In the typical conditioned suppression or conditioned emotional response (CER) procedure, stable reference behavior is maintained by a variable interval (VI) schedule of positive reinforcement, and periodically during the session a conditioned stimulus (CS) is presented for a fixed duration. Coincident with CS termination a shock is automatically delivered regardless of subjects' behavior during the CS. The repeated finding with shock has been that ongoing, positively-reinforced behavior is suppressed in the presence of pre-shock stimuli (viz., Estes and Skinner, 1941; Brady and Hunt, 1955; Hunt and Brady, 1955; Stein, Sidman, and Brady, 1958; Annau and Kamin, 1961; Hoffman and Fleshler, 1961; Lyon, 1963). The present experiments compared the effects of different aversive stimuli (time-out

from positive reinforcement, loud sound, and electric shock) in the conditioned suppression paradigm.

EXPERIMENT I

Ferster (1958, Exp I) found that chimpanzees' base line rate of response accelerates in the presence of a stimulus that precedes a period in which reward is unobtainable (TO). Herrnstein (1955), in an unpublished thesis, had previously reported a similar finding for pigeons when the VI schedule interrupted by TO had relatively long mean intervals between reinforcements, such as 7 and 9 min. Herrnstein also found that when the VI schedule had a mean interval of 7 min and the TO duration was increased from 30 sec to 50 min, the degree of response acceleration in the presence of the pre-TO CS progressively increased. Since "conditioned suppression" refers to when responses are reduced during a CS preceding shock, it will be convenient to speak of "conditioned acceleration" when responses are increased during a CS preceding TO.

Both Ferster and Herrnstein in their studies with TO, used a procedure somewhat different from the usual response-independent CER procedure employed with shock. In their studies, the first response after the CS has been on for 30 sec produced the TO; the longer the subject delayed responding, the longer the CS remained on and the longer TO was delayed. It is not clear, therefore, whether the difference in the contingency or the difference in the nature of the event is responsible for conditioned

acceleration. In the present study, different colored key lights signaled shock and TO, enabling a comparison within individual pigeons of the effects on ongoing behavior of pre-shock and pre-TO stimuli. This comparison was made using both the usual CER response-independent procedure and the response-contingent procedure that Ferster and Herrnstein have each used with TO.

Subjects

Four naive, adult, white Carneaux barren hen pigeons, obtained from the Palmetto Pigeon Plant, were kept at approximately 75% of normal body weight throughout the experiment. Water was freely available in the home cages and in the experimental boxes.

Apparatus

Two Lehigh Valley pigeon boxes, model 1519, each containing one accessible key were used. Red and green lights mounted behind the translucent plastic key served as discriminative stimuli for shock and TO respectively. Between these CS presentations the key was illuminated by a white light.

Reinforcement was a 3-sec exposure to a food hopper containing a mixture of 50% Kaffir, 40% Vetch, and 10% Hempseed. During reinforcement a white light in the hopper was turned on, but house and key lights were not turned off.

Shock was delivered via gold wire electrodes implanted around the pubis bones of the pigeon (Azrin, 1959). Retractile, coiled power cord was plugged at one end into a harness worn by the pigeon and at the other end into a freely turning telephone jack located in the ceiling of the box. Alternating current line voltage controlled by a variable step-down transformer was the shock source; a separate shock source was used for each bird in a yoked pair. The shock source was connected in series through a 10,000 ohm resistor to the pigeon. By setting a given voltage and measuring the impedance of the bird, it was possible to specify shock intensity in terms of current. The shock duration was 40 msec.

The experiment was programmed with timers, steppers, tape programmers, and appropriate relay circuitry, and recorded from running time meters, electromechanical counters, and cumulative recorders.

Procedure

Each pigeon was first trained to peck the key for food reinforcement. Reinforcement was programmed at irregular intervals with the mean time between successive reinforcements set at $2\frac{1}{3}$ min (VI $2\frac{1}{3}$ min schedule of reinforcement). Training continued until relatively stable performance developed during and across successive sessions. Following this, each bird received 30, 2-hr adaptation sessions, in which each CS was presented five times per session without subsequent shock or TO. In each session, presentation of the first CS was usually delayed about 15 min from the start or in some instances longer if the bird was not responding in a stable manner. The CS duration was 30 sec, and the CS sequence remained the same throughout the experiment: green, red, red, green, red, green, green, red, green, red. There was a 9-min interval between termination of one CS and onset of the next.

After this CS adaptation period, electric shock and TO were introduced after their respective CS—red key light before shock and green before a 10-min TO. The TO's increased the length of the session to 2 hr and 50 min. Different birds were started with different shock intensities: Pigeon 1 (1 ma); Pigeon 2 (3.5 ma); Pigeon 3 (2 ma); Pigeon 4 (2.5 ma). Pigeon 3 received 2 ma for the first session only and then was switched to 1 ma. All pigeons did not receive equal shock intensities because another phase of this experiment, not reported here, required varying shock intensities within individual birds and they were started at different levels to counteract possible sequential shock effects. During TO the key light was turned off, the VI tape programmer and motor drive of the cumulative recorder were stopped, and the circuit leading to food reinforcement was disconnected. The house lights remained on during TO to avoid confounding the effects of complete darkness with the effects of absence of reward.

For Pigeon 1 and Pigeon 4, shock and TO were response contingent, while for Pigeon 2 and Pigeon 3, shock and TO were response independent. In the response-contingent procedure, the first response that occurred 30 sec after the color of the key light had been changed from white to red or from white to green produced shock or TO respectively. Each CS was maintained until a response was

made. A yoked procedure was employed so that each pigeon assigned to the response-independent procedure received shock or TO at the same time as the pigeon assigned to the response-contingent procedure. Pigeons 1 and 2 were yoked together, and the other yoked pair was made up of Pigeons 3 and 4. This yoking procedure was mainly motivated by programming convenience and not by a major desire to make between-subject comparisons; there were only two pairs, and since members of a pair received different shock intensities such a comparison would be of dubious value. Although minimum CS duration was 30 sec, the longer the bird assigned to the response-contingent procedure delayed responding, the longer was the CS duration and the CS-shock or CS-TO interval. On the other hand, behavior of the bird assigned to the independent condition did not influence the occasion for shock or TO. A visual stimulus was used to help distinguish the response-contingent procedure from the response-independent procedure. A solid black circular spot approximately ¼ in. in diameter was located in the center of the key when the response-independent procedure was in effect, but no circle was present when the response-contingent procedure was in effect. Pigeon 1 received 30 contingent sessions, followed by 20 response-independent sessions, and then another 20 response-contingent sessions, while Pigeon 2 received the reverse sequence: 30 independent, 20 contingent, and 20 independent sessions. Pigeon 4 received 30 contingent sessions, 20 independent sessions, and 40 contingent sessions. Pigeon 3 received 25 independent sessions, 35 contingent sessions, and another 35 independent sessions. After receiving the first shock, Pigeon 3 turned its back on the key whenever a CS was presented and seemed unable to discriminate between the red and green CS. Just before session 26, Pigeon 3 received several retraining sessions with the key light red throughout, and several retraining sessions with the key light green throughout. These procedural variations were carried out to reinstate responding in the presence of each CS. Shock was removed during sessions 26-45 but TO was left in.

Results

Figure 1 compares the effects of the pre-TO CS with the effects of the pre-shock CS for each pigeon. The dependent variable is expressed

as a ratio of two frequencies: CS/pre-CS. Total response frequencies per session in pre-CS control periods (30 sec preceding each CS) were divided into total response frequencies per session in associated CS periods. No matter how long the CS duration was, however, only responses in the first 30 sec of each CS were considered in calculating the ratios. The means of these ratios for blocks of five sessions are plotted in Fig. 1. A ratio above 1.00 indicates response acceleration, and a ratio below 1.00 indicates response suppression.

For Pigeons 1, 2, and 4 response rate consistently accelerated above control levels in the presence of the pre-TO CS, but declined below control levels in the presence of the pre-shock CS. The results for Pigeon 3 were not so clear-cut and suggest considerable induction effects between the pre-shock and pre-TO stimuli. There was no evidence of the conditioned acceleration effect adapting out over the large number of sessions and CS presentations. Acceleration was maintained for about 325 CS presentations for Pigeon 1, about 350 CS presentations for Pigeon 2, about 300 CS presentations for Pigeons 3, and about 400 CS presentations for Pigeon 4.

Figure 1 does not show any consistent difference in effects between the response-contingent and response-independent procedures for either the pre-TO CS or the pre-shock CS. Generally, the degree of conditioned acceleration during the final contingent series approximates more closely the degree in the preceding independent series than in the original contingent series. The same is true of conditioned suppression and a similar sequential effect is present for yoked subjects tested in the reverse order. In another phase of this experiment (for details see Leitenberg, 1965b) it was found that even when subjects were shifted every two days from one procedure to another, key pecking behavior continued to accelerate during the pre-TO CS and decelerate during the pre-shock CS whether TO or shock were independent of or contingent upon a response.

Representative portions of cumulative records illustrating conditioned acceleration and conditioned suppression in each bird are presented in Fig. 2. Response acceleration appeared to be constant throughout the pre-TO CS.

During TO, response rates declined to negligible levels in a short number of sessions. For
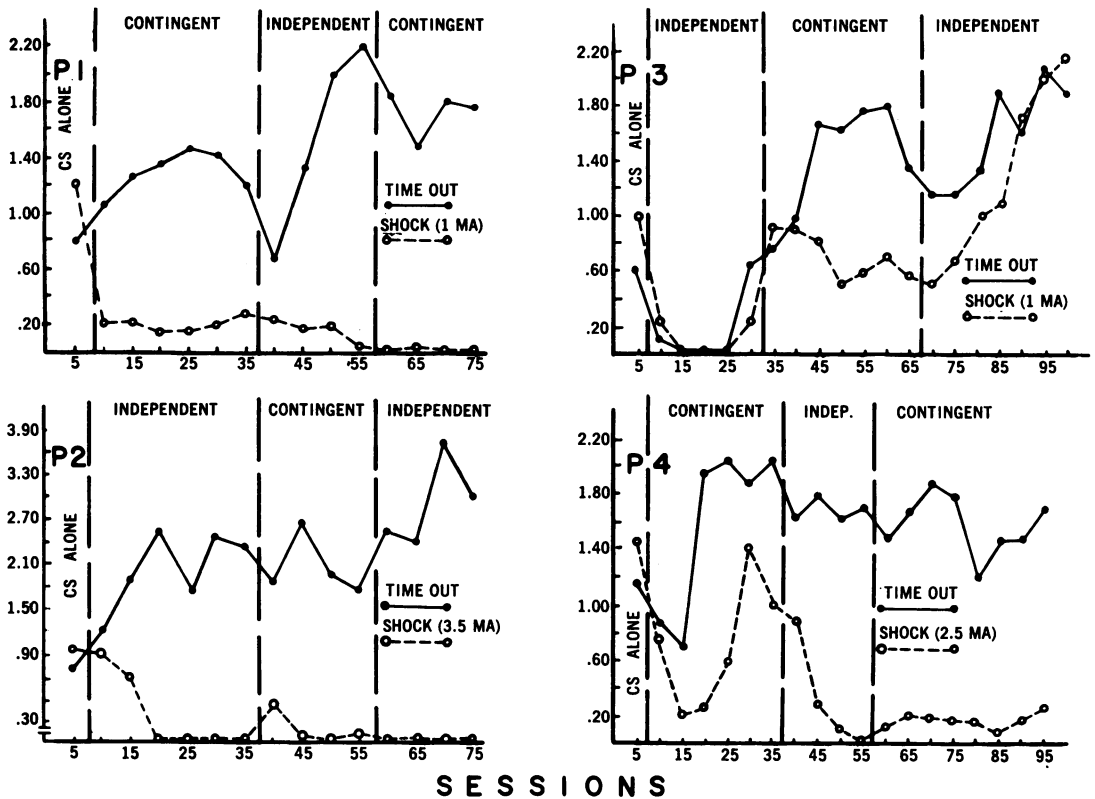
Fig. 1. Mean CS/pre-CS ratios for TO and for shock as a function of sessions employing response-contingent or response-independent procedures.

instance, in the first block of 10 sessions the mean rate of response per minute during TO was for Pigeon 1: 0.8, for Pigeon 2: 6.0, for Pigeon 3: 0.7, for Pigeon 4: 1.0. This compares with VI response rates per minute of 22.35, 21.56, 38.52, and 30.92. Although it is interesting that the pigeon which responded most during TO, Pigeon 2, also showed the greatest degree of conditioned acceleration, this relationship was not corroborated in Exp II.

EXPERIMENT II

The results of Exp I leave undecided the question of whether the difference between the effects of the pre-TO CS and pre-shock CS was a function of qualitative (type of stimulus) or quantitative (intensity) differences between the aversive stimuli. Is the conditioned acceleration effect specific to TO, or is it characteristic of other weak aversive stimuli that, like TO, are presumably less effective than moderate levels of electric shock in punishment (e.g., Holz and Azrin, 1963), avoidance, or escape

paradigms? It has already been demonstrated that low shock intensities do not evoke conditioned acceleration. Annau and Kamin (1961) found that .28 ma, the weakest shock they studied that failed to produce conditioned suppression, did not produce conditioned acceleration either. In their study, response rate during the pre-shock CS was about the same as response rate in the absence of the CS.

The purpose of the present experiment was to compare in individual pigeons the effects on reference behavior of a pre-TO CS with a CS that precedes another alleged mild aversive stimulus, loud noise. Although loud noise in the 95-110 db range has been shown to have aversive properties in a host of studies with rats, only one study has been done with pigeons. Holz and Azrin (1962) demonstrated the punishing effects of loud noise with pigeons, using an intensity of 137 db.

Only the typical response-independent CER procedure was employed in the present experiment. When loud noise was found to have essentially no effect, a loud tone was substituted
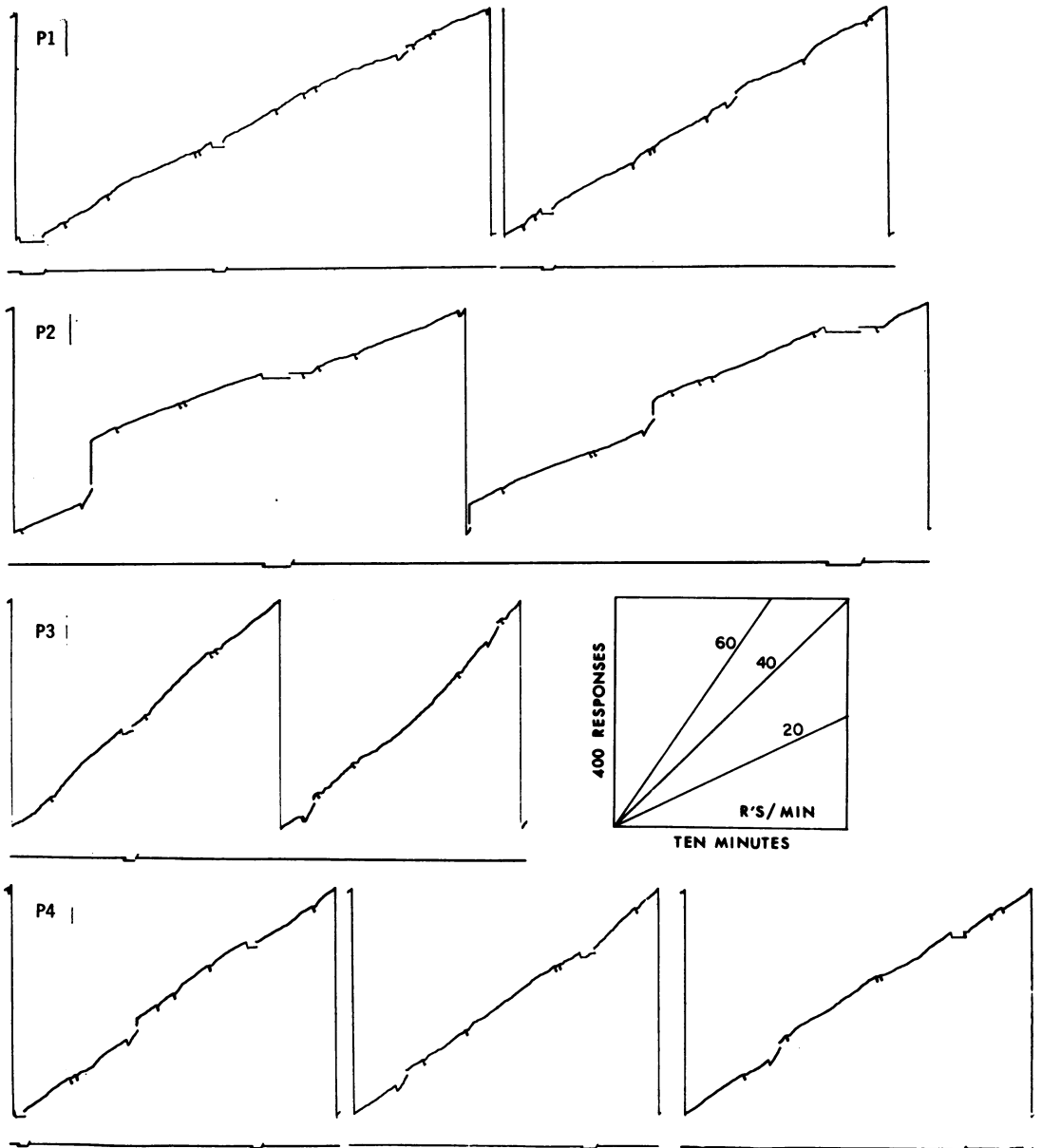
Fig. 2. Sample cumulative records illustrating conditioned suppression and conditioned acceleration in individual pigeons. Reinforcements are indicated by a brief downward displacement of the response pen, except during the CS when they are indicated by a brief upward displacement. Simultaneous offset of the response pen and the event pen identifies the pre-shock CS. During the pre-TO CS the response pen alone is offset. A vertical rise at the end of the pre-TO CS is due to the fact that the paper drive, but not the pen drive, on the cumulative recorder was stopped during TO.

in its place. Since humans verbally report that loud tones of limited frequency are more "piercing" than white noise of the same intensity, some difference in effect seemed possible for the conditioned suppression paradigm. No previously published report of the use of loud

noise or loud tone in the CER paradigm was found.

Subjects

Three naive, adult, male white Carneaux pigeons were maintained at 75% of normal

body weight, and water was always available.

Apparatus

The same apparatus was used as in Exp I. The source of white noise was a Grason-Stadler noise generator (model 901 A). The source of the 1000 cps tone was an Ameco Code Practice oscillator. The intensity of noise and tone as measured by a General Radio Co. sound level meter (Type 759) at the level of the pigeon's head in the experimental box was 115-120 db and 110 db respectively (ref., .0002 dynes/cm²). The duration of noise or tone was 3 sec.

Procedure

The frequency of each CS in a session, the time between each CS occurrence, the sequence of CS occurrences, the VI schedule of reinforcement, session length, and the TO duration were all the same as in Exp I. First 30 CS adaptation sessions were run, and then noise and TO were introduced after their respective CS. After each CS had been in effect for 30 sec, noise or TO automatically occurred. The red CS preceded TO and the green CS preceded first noise (30 sessions) and then tone (20 sessions). Association of the TO with the red CS in this experiment, rather than with the green, provided a control for possible direct effects of key color.

RESULTS

The major finding of Exp II is that the pre-TO CS caused ongoing behavior to accelerate as before, while the pre-noise and pre-tone CS produced no significant change. As can be seen in Fig. 3, the green CS had the same effects when noise or tone followed it as when nothing followed it.

As Fig. 3 indicates, conditioned acceleration was not as great nor as consistent for subjects in this experiment as in Exp I. As before, however, no systematic decline in successive sessions was noted. Apparently the conditioned acceleration effect is long lasting.

The results of this experiment indicate the irrelevancy of key color, since the color of the key light producing acceleration was the same as the color producing suppression in the previous experiment. Also, since conditioned acceleration during the pre-TO CS was present in this experiment, even though conditioned

suppression was absent in the presence of the other stimulus, it is unlikely that acceleration is a function of some "contrast" effect.

DISCUSSION

Ongoing behavior is affected differently by stimuli signaling TO, loud sound, and shock. Moreover, the differences lie in direction, not merely in degree of effect. Pre-shock stimuli suppress ongoing behavior, pre-TO stimuli accelerate behavior, while pre-noise stimuli have little or no effect.

Ferster's (1958) explanation of the conditioned acceleration phenomenon is based on the fact that TO was response contingent in his study. He argues that if few responses are made in the pre-TO CS period, the likelihood of a TO following any one response is greater than if many responses are made. When there is a high rate of response during the CS, only one of many is punished, and those responses that follow shortly after another are less likely
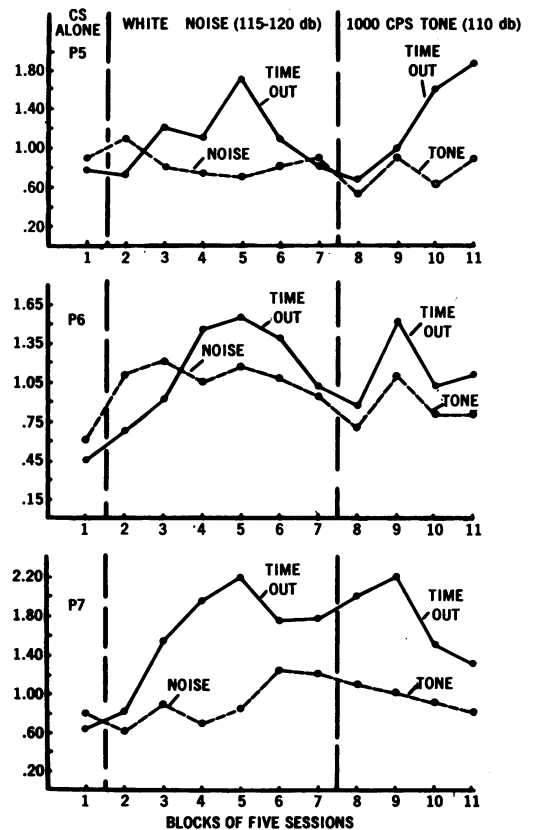

Fig. 3. Mean CS/pre-CS ratios over sessions as a function of the kind of events following each CS: TO, loud noise, or loud tone.

to produce a TO than more widely spaced responses. Generally then, there is a higher frequency of punishment for widely spaced responses than for responses that have short interresponse times. Hence, in the presence of the pre-TO CS, response rates accelerate above control levels. Logically, this same analysis applies equally well when shock is contingent upon the first response after a fixed CS duration. If it is the contingency rather than the nature of the event that determines conditioned acceleration, then response independent TO might be expected to give suppression like response-independent shock, and response-contingent shock might be expected to yield conditioned acceleration. The results of Exp I suggest that both these hypotheses are incorrect. Conditioned acceleration in the presence of the pre-TO CS and conditioned suppression in the presence of the pre-shock CS occur whether the procedure for presenting shock or TO at the end of the CS was response contingent or response independent.

This agrees with the findings of other investigators. In various other ways, previous studies have compared the effects of response-contingent shock and response-independent shock in a CER related paradigm. Although there is some disagreement as to which procedure produces greater response suppression—the data from Hoffman and Fleshler (1965) suggest the response-independent procedure, the data from Azrin (1956) suggest the response-contingent procedure, and the data from Hunt and Brady (1955) suggest no difference—all the data agree that neither procedure accelerates response rate.

In studies related to TO, Pliskoff (1961, 1963) found an increase in response rate in the presence of a stimulus preceding a response-independent shift to a lower reinforcement frequency component of a multiple schedule. Apparently the effects of a temporary reduction in frequency of food reinforcement are quite similar to the effects of a temporary omission of food reinforcement in the conditioned suppression paradigm.

Why then, if the contingency is not responsible, does key pecking frequency accelerate in the presence of the pre-TO CS? Suppression of base level responding in the presence of a pre-shock CS supposedly reflects a conditioned emotional response (CER) which disrupts ongoing behavior (*e.g.*, Hunt and Brady, 1955).

Terms such as conditioned "fear" and conditioned "anxiety" have been used to describe the nature of this emotional response and in rats, at least, crouching, freezing, and defecation are observable components of the CER. These are supposed to be unconditioned responses to shock which become conditioned to the CS preceding shock. Perhaps conditioned acceleration is a quantifiable reflection of anticipated "frustration" like conditioned suppression is supposedly a quantifiable reflection of anticipated "pain." The unconditioned response to omission of reward is heightened activity and emotionality (*e.g.*, Keller and Schoenfeld, 1950, p. 328; Amsel, 1958, 1962; Notterman, 1959; Wagner, 1959, 1963; Thompson, 1961, 1962). Accordingly, in the present study, it is possible that the energizing effects evoked by TO become conditioned to the pre-TO CS and are reflected by an increase in rate of the predominating, still positively-reinforced behavior, key pecking. Direct tests of this hypothesis remain to be made.

Does the finding of the present experiment, that TO and loud auditory stimulation act differently than shock in the CER paradigm, mean that TO, loud noise, and loud tone are not aversive stimuli? Sufficient data already exist to conclude otherwise, *i.e.*, these stimuli in common with shock can punish behavior, are avoided, are escaped from, and have secondary negative reinforcing properties. [See Leitenberg (1965a) for a review of the aversive properties of TO.] Instead of inferring, therefore, that the absence of conditioned suppression signifies a stimulus without aversive properties, it seems more reasonable to conclude that either conditioned suppression is not an inherent characteristic, or is not a sensitive index, of an aversive stimulus. The results from Exp I and II also suggest that conclusions regarding the properties of aversive stimuli should not be based solely on results obtained with electric shock. It appears that electric shock may not be as representative of the class of aversive stimuli as is generally assumed.

Although the present data concerning loud sound and previous data concerning the effects of low intensity shock suggest that conditioned acceleration is a specific effect of TO rather than a general effect of mild aversive stimuli, a more definitive statement must await further investigation. Intensities, durations, and frequencies of a variety of aversive stimuli—

such stimuli being defined by their functional effects in avoidance, escape, and punishment paradigms—have yet to be systematically manipulated in the CER paradigm.

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