**POSITIVE REINFORCEMENT AND SUPPRESSION FROM
THE SAME OCCURRENCE OF THE UNCONDITIONED
STIMULUS IN A POSITIVE CONDITIONED
SUPPRESSION PROCEDURE¹**

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Responding of rats was maintained on a variable-interval schedule of food reinforcement. The same response also produced a blinking light followed by electrical brain stimulation according to a fixed-interval schedule. This conjoint schedule produced two behavioral changes. First, instead of a steady rate of responding throughout the session, which would be characteristic of the variable interval food schedule alone, responding between occurrences of the light-brain stimulation pairings became positively accelerated and thus was more characteristic of the fixed-interval schedule of these pairings. Second, food responding was suppressed during the light that preceded brain stimulation. These results indicate that positive reinforcement and suppression resulted from the same occurrence of the light-brain stimulation combination. This finding suggests that stimuli such as conditioned reinforcers that precede an unconditioned reinforcer may have a suppressive effect upon responding in their presence that is being maintained by another reinforcer.

In the conditioned suppression phenomenon (Estes and Skinner, 1941) responding maintained by a positive reinforcer, *e.g.*, food, is suppressed during occasional presentations of a conditioned stimulus (CS), *e.g.*, a tone, that has been paired with electric shock, the unconditioned stimulus (UCS). Estes and Skinner (1941) stated that the suppression during the CS resulted because the CS was paired with a "disturbing" or aversive UCS. Another possibility is that conditioned suppression results when a CS is paired with any strong UCS, be it positive or negative. Azrin and Hake (1969) tested this possibility by pairing a CS with positive unconditioned stimuli such as food, water, and reinforcing brain stimulation instead of aversive shock. They reported that responding was suppressed during the CS and they called the procedure "positive conditioned suppression" to distinguish it from the

usual aversive or negative conditioned suppression procedure.

Due in part to the fact that there are no scheduled contingencies between responses and the UCS, both positive conditioned suppression (Azrin and Hake, 1969) and negative conditioned suppression (see review by Lyon, 1968) have usually been interpreted in terms of respondent conditioning, rather than operant conditioning. The distinction between positive and negative conditioned suppression, however, depends upon operant conditioning. The distinction implies that the UCS that produces the suppression in a positive conditioned suppression procedure could simultaneously function as a positive reinforcer. Similarly, the distinction also implies that the UCS that produces suppression during a negative conditioned suppression procedure could simultaneously function as a negative reinforcer. Since there is no measure of these operant effects in the usual conditioned suppression procedure, questions may arise concerning these operant effects. That is, in a given conditioned suppression experiment, can the UCS really be designated as a positive or negative reinforcer? For example, in the Azrin and Hake (1969) study of positive conditioned suppression, reinforcing brain stimulation (ICS) was used as one of the unconditioned stimuli to reduce the possibility that

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the suppression during the CS might be due to competing, preparatory consummatory responses that might occur during a CS when food or water serves as the UCS. The use of ICS does not preclude preparatory responses, but its mode of delivery is similar to aversive shock of the negative conditioned suppression procedure in that no consummatory response is required. Although the ICS was shown to be a positive reinforcer before it was used in the positive conditioned suppression procedure, there was no evidence that it could have functioned as a positive reinforcer while the positive conditioned suppression procedure was in effect. There is evidence that the reinforcing properties of the ICS can change over time such that the ICS may have been a negative rather than a positive reinforcer during the positive conditioned suppression procedure. Steiner, Beer, and Shaffer (1968) have shown that ICS presented at prearranged times can function as a negative reinforcer even when subjects have previously responded to produce ICS at that same rate of presentation. Also, physiological factors such as changes in electrical resistance or seizures can affect the reinforcing properties of ICS. It is also possible that an emotional state and/or the reduction in responding during a CS constitute negative reinforcers that override the positive properties of the CS-UCS combination. Thus, a question may exist as to whether the CS-UCS combination is a positive or a negative reinforcer in a positive conditioned suppression procedure.

It seems most likely, however, that the CS-UCS combination of a positive conditioned suppression procedure would be shown to function as a positive reinforcer if means were available to measure its effect during the conditioned suppression procedure. The UCS should function as an unconditioned reinforcer and the CS, through pairing with the UCS, should function as a conditioned reinforcer. If the CS-UCS combination was made contingent upon responding and it did function as a positive reinforcer, would the CS still suppress other responding in its presence that is being maintained by another reinforcer? If so, positive reinforcement and suppression would result from the same occurrence of the CS-UCS combination. Such a finding would suggest that stimuli such as conditioned reinforcers that precede an unconditioned rein-

forcer may suppress responding in their presence that is being maintained by another reinforcer. A procedure that could simultaneously measure the positive reinforcing and suppressive effects of the CS-UCS combination of a positive conditioned suppression procedure is needed to answer the above questions.

Hake and Azrin (1965) evaluated the response-contingent effects of the CS in a negative conditioned suppression procedure by arranging for the CS alone to be contingent upon the food-motivated responding between the CS-UCS pairings. In that experiment, the responses that produced the CS were suppressed and the CS was designated as a conditioned punisher. A similar procedure could be used to evaluate the reinforcing effects of the CS-UCS pairings of a positive conditioned suppression procedure. That is, the baseline responding that is being maintained on one schedule of food reinforcement could also produce the CS-UCS pairings according to a second schedule of reinforcement. In this way, the positive reinforcing effects of the CS-UCS pairings could be evaluated in terms of changes in the rate and/or pattern of responding between the CS-UCS pairings. For example, in the present experiment, baseline responding was maintained on a variable-interval (VI) schedule of food reinforcement, which typically produces a relatively steady rate of responding (Ferster and Skinner, 1957). The baseline responding also produced a 10-sec blinking light that ended with a train of reinforcing brain stimulation. These CS-UCS pairings were scheduled according to a fixed-interval schedule (FI), which typically results in a positively accelerated rate of responding between positive reinforcers (Ferster and Skinner, 1957) and a negatively accelerated rate of responding between punishers (Azrin, 1956). Hence, if the CS-UCS combination did function as a positive reinforcer or as a punisher, the pattern of responding between the CS-UCS presentations would be characteristic of the FI schedule of the pairings instead of the VI food schedule, and the properties of the CS-UCS combination could be determined by examining the nature of the FI pattern. Reinforcing brain stimulation was used as the UCS to reduce the possibility that the suppression of food responding during the CS might be due to competing, preparatory consummatory responses to the UCS.

EXPERIMENT I

METHOD

Subjects and Apparatus

Six experimentally naive, 90- to 120-day-old rats of the Sherman Sprague-Dawley strain served.

The experimental compartment, which measured 13 by 11.75 by 13.75 in. (33 by 30 by 35 cm) high was inside a sound-attenuating, ventilated chamber. A swivel and pulley arrangement above the chamber allowed the animals to move freely without twisting the electrode leads. The chamber always contained one of three response manipulanda—a lever (Lehigh Valley Electronics Rat Lever #1352), a 0.75 in. (1.9-cm) diameter Gerbrands pigeon key, or a 7.75 in. (20-cm) chain that was suspended from the center of the ceiling. The key and bar were located 2 in. (5 cm) from the floor and 4.75 in. (12 cm) to the left of the food tray. All three response manipulanda required about 15 g (0.14N) of force to activate. A 1.25 in. (3-cm) diameter red stimulus light that blinked at a rate of 10 Hz was 6 in. (15 cm) above the location of the lever or the key. Each blink of this 6-w stimulus light changed the illumination throughout the chamber and was accompanied by a low-intensity click from an enclosed relay. A much louder and distinctively different click from a power relay mounted on the front panel provided feedback for the lever and key responses. A 4.7-w overhead light that was shielded on the front and top was located at the top of the front wall. It provided dim but continuous illumination except during food delivery when the food tray was illuminated. Water was continuously available from a tube that extended down from the ceiling.

The intracranial stimulation (ICS) was a series of 0.5-sec pulse trains of 100-Hz biphasic rectangular pulses, each pulse having a duration of 0.2 msec with a 0.1-msec delay between pulses. A series consisted of 10 of the 0.5-msec pulse trains, each train following the previous one by 40 msec. Current and waveform were monitored on an oscilloscope.

Procedure

Electrode implantation. One week before the first session the 0.25-mm diameter, bipolar, stainless steel electrodes were implanted stereo-

tactically under Nembutal anesthesia using a procedure similar to that described by Miller, Coons, Lewis, and Jensen (1961). The electrodes were aimed at the lateral hypothalamus.

Pre-testing. The optimal intensity of ICS that would maintain responding was individually determined for each subject during sessions in which the subjects were conditioned to respond for ICS using a different response manipulandum and different stimulus conditions than were used in the experiment proper. Intensities ranging from 300 to 600 microamperes (zero to peak) were found to maintain a chain-pulling response when each response was followed by one 0.5-sec pulse train. This fixed-ratio 1 schedule was in effect until the animals responded at the start of a session without priming. Then, the procedure was changed so that the first chain pull during a 10-sec presentation of the houselight produced a series of 10 of the 0.5-sec pulse trains and terminated the houselight. The houselight was initially presented every 30 sec to 1 min and finally every 2 min, the rate the CS was scheduled to occur in the experiment proper. When the houselight was presented every 2 min in a 90-min session, all subjects responded in at least 90% of the presentations.

The experiment. After pre-test and deprivation to about 80% of free-feeding weight, the subjects were conditioned to press the bar (Rats 3, 4, and 6) or to push the key (Rats 1, 2, and 5) for 45-mg Noyes food pellets. Over the next 5 to 10 sessions, the schedule of reinforcement was changed from fixed ratio-one (FR 1) to VI-30 sec, to VI-2 min, to VI-3 min. Daily 90-min sessions were given on the VI-3 min schedule until response rates within sessions were relatively uniform (three to eight sessions for different subjects). Then, the subjects were started on either the experimental (contingent CS) or the control (non-contingent CS) procedure. Under the contingent CS procedure, the first response after a fixed interval of 2 min (FI-2 min) also produced the CS (10-sec blinking red stimulus light and click) whereas under the non-contingent CS procedure, the CS occurred every 2 min independent of responding. The non-contingent CS procedure was used to determine the effect of the CS-UCS presentations *per se* upon the pattern and rate of responding between presentations. Under both procedures, the VI-3 min schedule of food reinforcement was in effect throughout the ses-

sion. Presentation of a food reinforcer during the CS had no effect upon the duration of the CS. Sessions lasted for 40 CS presentations or 100 min, whichever came first. After three to five sessions with the CS alone, the ICS was presented at the end of the CS for 5 to 18 sessions. The ICS was then discontinued for three more sessions for all of the subjects except R-3 and R-6, which were terminated after their last ICS session because their electrodes came out. Of the first four subjects, two were tested on the contingent CS procedure (R-1, R-3) and two on the non-contingent CS procedure (R-2, R-4). The last two subjects (R-5, R-6) were exposed to both procedures but in different orders: R-5 was initially tested under the non-contingent CS procedure and R-6 was initially run under the contingent CS procedure.

Pre-feeding. A conditioned suppression effect under the contingent-CS procedure requires that there be food-motivated responding and that the rate of this responding be higher in the absence of the CS than during its presence. In order to determine whether there was food-motivated responding and whether the rate of such responding was re-

duced during the CS, the subjects were pre-fed (to satiation) for one session in which the ICS was in effect; the response rates in this session were then compared to the response rates in the preceding and subsequent sessions with food deprivation. It was assumed that the pre-feeding would reduce the rate of food-motivated responding and that the absolute amount of the reduction would be a function of the level of food-motivated responding without pre-feeding. That is, if there were conditioned suppression, the pre-feeding probe would reduce the rate of responding and the reduction in the absence of the CS would be larger than that during the CS.

Histology. After the experiment the animals were sacrificed, perfused with normal saline followed by a 10% formalin solution, and their brain tissue sectioned and photographed according to the procedure described by Hutchinson and Renfrew (1967). The location of the electrode tip of each of the six animals in Exp. I and the two animals in Exp. II was determined and is shown in Fig. 1 on a schematic of a frontal brain section from the Pellegrino and Cushman (1967) rat stereotaxic

Fig. 1. Location of electrode tips for Exp. I (R-1 and R-6) and Exp. II (R-7 and R-8) illustrated on schematics of frontal sections of the rat brain. The number above each section identifies the plate of the Pellegrino and Cushman (1967) rat stereotaxic atlas from which the section was copied.

atlas. The major areas of the brain are indicated on the drawings and the coordinates are given in millimeters along the ordinate and the abscissa. It can be seen that all the electrode tips were in the lateral hypothalamus with the exception of the electrode of R-6, which bordered the ventral tegmental nucleus.

RESULTS

Figure 2 shows the effects of the CS-UCS combination upon the pattern of responding between CS-UCS presentations. First, it can be seen that without the UCS (ICS off), responding occurred at a relatively constant rate between CS presentations and increased during the CS. This constant response rate between CS presentations without the UCS is in contrast to the positively accelerated rate of responding between presentations when the UCS (ICS on) was present under the contingent-CS procedure (left half of figure). This positively accelerated responding, characteristic of an FI schedule of positive reinforcement, was followed by a reduction in responding during the CS. On the other hand, it can be seen that presenting the CS-UCS combination every 2 min independent of behavior (right-hand side of Fig. 2) did not produce a FI pattern of responding with the exception of R-6, the subject that was initially tested under the contingent-CS procedure. The CS-UCS pairings of this more conventional conditioned suppression procedure also resulted in a reduced rate of responding during the CS. It should also be noted that under the non-contingent-CS procedure, and to a lesser extent under the contingent-CS procedure, the reduction in response rate was largely but not entirely restricted to the CS; the addition of the UCS also frequently reduced the rate of response in the absence of the CS.

Figure 3 shows that the response rate during the CS became lower than that in the absence of the CS soon after the UCS was introduced. In this figure, the response rate during the CS is expressed relative to the response rate in the absence of the CS using a suppression ratio of $A/(A+B)$ in which A is the response rate during the CS and B is the response rate between CS presentations. Before the UCS (ICS off) was introduced, the ratios were over 0.5, which indicates that the CS alone had a facilitative effect upon responding. However, within one session after the UCS was intro-

Fig. 2. The rate of responding during the six consecutive 20-sec intervals between CS presentations and during the 10-sec CS. The response rates without the UCS (ICS off) represent averages of the three sessions immediately preceding the introduction of the UCS and, with the exception of R-3 (contingent-CS) and R-6 (non-contingent-CS), the three sessions immediately after the UCS was discontinued. The response rates with the UCS (ICS on) for Subjects 1, 2, 3, and 4 (top half of figure) that were exposed to only one CS procedure are averages of the third, fourth, and fifth sessions that the UCS was presented. These sessions were selected because one of the subjects was run with the UCS for only five sessions. R-3 was run for 13 sessions with ICS and Sessions 11, 12, and 13 are also shown (indicated by Xs). For Subjects 5 and 6 (bottom half of figure) that were exposed to both CS procedures, the response rates with the UCS are averages of the last three sessions that the UCS was presented under each CS procedure. These two subjects were exposed to the same number of sessions with the UCS (16 for R-6) or nearly the same number (six or eight for R-5) under each CS procedure. The sequence of the procedures for these two subjects is indicated by the letters A (first procedure) and B (second procedure). Note that the ordinate for R-1 has been reduced to accommodate the higher response rates of this subject.

Fig. 3. Suppression ratio for each session. The figure shows the suppression ratio for three sessions before the UCS was introduced, all sessions with the UCS, and the three sessions immediately after the UCS was discontinued. Subjects 1, 2, 3, and 4 in the top half of the figure were exposed to either the contingent-CS procedure or the non-contingent-CS procedure. Subjects 5 and 6 in the bottom half of the figure were exposed to both the contingent- and non-contingent-CS procedures. The sequence of the procedures is indicated by the letters A (first procedure) and B (second procedure). The pre-feeding sessions have been omitted in the figure.

duced, the suppression ratios were below 0.5 and, with the exception of R-1, were consistently below 0.5 as long as the UCS was in effect. The ratios returned to 0.5 or more the first or second (R-4) session that the UCS was discontinued.

The reductions in responding during the CS under the contingent-CS procedure in Fig. 2 and 3 suggest conditioned suppression, but alone they do not provide sufficient evidence. It is still possible that all of the responding was being maintained by ICS and the responding decreased during the CS because there was no ICS response requirement during the CS. In order to have conditioned suppression under the contingent-CS procedure, there must be food-motivated responding and the rate of such responding must be higher in the absence of the CS than during its presence. That the subjects consumed their food pellets does suggest food-motivated responding, but it is

not sufficient evidence and it does not indicate whether food responding was suppressed during the CS. The pre-feeding probes were used to determine whether the rate of food responding was reduced during the CS. It was assumed that pre-feeding would reduce the rate of food-motivated responding and that the absolute amount of the reduction would be a function of the level of food-motivated responding without pre-feeding. Simply, if there were a conditioned suppression effect, the pre-feeding probes should reduce the rate of responding, and the reduction in the absence of the CS should be larger than that during the CS. That this was the effect of pre-feeding can be seen in Table 1. The reduction in rate resulting from pre-feeding may not indicate the absolute level of responding maintained by food, since pre-feeding may not completely eliminate food-motivated responding. However, the reductions resulting from pre-feeding indicate that most of the responding in the absence of the CS was maintained by food. Without pre-feeding, responding during the CS was already reduced to as little as 5% to 30% of the rate in the absence of the CS for three of the subjects (3, 5, and 6) and for these subjects a conditioned suppression effect is clear. For these subjects, the effect of pre-feeding was much greater in the absence of the CS than during its presence. This was also the case for the subject (R-1) whose responding had been reduced only slightly during the CS under the usual contingent-CS procedure (row 1). This subject had the highest response rate immediately before the CS (Fig. 2) and this rate carried over into the early part of the CS period. The fact that pre-feeding reduced the rate of responding in the absence of the CS but not during the CS suggests that food responding was already reduced during the CS and that the responding that remained there was being maintained by the production of the CS and the ICS rather than food.

DISCUSSION

These results suggest that positive reinforcement and suppression can result from the same occurrence of a stimulus. Responding in the absence of the CS was reinforced by the CS-UCS combination, whereas food responding during the CS was suppressed. That the UCS was a reinforcer is indicated by the schedule control that resulted when the CS-UCS com-

Table 1

Comparison of response rates under the contingent-CS procedure with and without pre-feeding.

	<i>R-1</i>		<i>R-3</i>		<i>R-5</i>		<i>R-6</i>	
	<i>Resp/Min</i> <i>Absence</i> <i>of CS</i>	<i>Resp/Min</i> <i>CS</i>	<i>Absence</i> <i>of CS</i>	<i>CS</i>	<i>Absence</i> <i>of CS</i>	<i>CS</i>	<i>Absence</i> <i>of CS</i>	<i>CS</i>
Contingent-CS	27.5	26.0	7.4	2.1	5.9	0.2	9.8	2.0
Contingent-CS with Pre-Feeding	8.7	27.9	0.0 ^a	0.0 ^a	2.1	0.3	0.8	1.0
Reduction Resulting from Pre-Feeding	18.8	—	7.4	2.1	3.8	—	9.0	1.0

^aR-3 produced the CS only once during the pre-feeding session.

bination was made contingent upon fulfilling the requirements of a fixed-interval schedule of reinforcement: the pattern of responding between CS-UCS pairings became positively accelerated, characteristic of the fixed-interval schedule of reinforcement. That this FI pattern of responding was due to operant conditioning, *i.e.*, the FI-response contingency, and not a respondent, non-contingent effect of the UCS alone was indicated by the absence of the FI pattern of responding when the UCS was presented independent of behavior at fixed intervals of time (non-contingent-CS procedure). Since both the fixed-interval schedule of ICS and the variable-interval schedule of food reinforcement controlled responding, the overall procedure may be best designated as a conjoint schedule, *i.e.*, two schedules programmed for one response (Catania, Deegan, and Cook, 1966; also see Kelleher and Cook, 1959).

A conditioned suppression effect under the contingent-CS procedure requires that there be food-motivated responding and that the rate of this responding be higher in the absence of the CS than during its presence. The pre-feeding probes under the contingent-CS procedure with ICS present reduced the rate of responding, and the reductions were larger in the absence of the CS than during it, thereby indicating that there was more food responding in the absence of the CS than during it. According to the pre-feeding probes, most of the responding in the absence of the CS was maintained by food. However, it is also possible that the change from 22- to 0-hr food deprivation in the pre-feeding session reduced ICS responding as well as the food responding. A relationship between the rate of ICS re-

sponding and food deprivation has been found when ICS responding was compared under 0- and 48-hr food deprivation (Brady, Boren, Conrad and Sidman, 1957; Hodos and Valenstein, 1960). If pre-feeding did reduce ICS responding in the present experiment, the reduction would be expected to be larger in the absence of the CS, since there was no ICS response requirement during the CS. Although Exp. I indicates that food responding was suppressed during the CS, a second experiment was conducted to provide a more definitive evaluation. In this experiment, the suppression of food-motivated responding under the contingent-CS procedure was evaluated by food-extinction probes instead of the food-satiation probes.

EXPERIMENT II

METHOD

Subjects and Apparatus

Two experimentally naive, 90- to 120-day-old Sherman Sprague-Dawley rats with electrodes implanted as described in Exp. I served. After the experiment, the brain tissue was prepared and photographed according to the procedure described in Exp. I. Figure 1 shows that the electrodes of both animals (R-7 and R-8) were in the lateral hypothalamus.

The apparatus was the same as in Exp. I.

Procedure

Pre-testing. The pre-testing procedure was the same as in Exp. I except that the bar-pressing response was used instead of chain pulling. The first bar press during a 10-sec

presentation of the houselight produced a series of ten, 0.5-sec pulse trains and terminated the light for 2 min. In both the pre-test and a post-test given after the experiment proper, both subjects responded during at least 90% of the houselight presentations in 60-min sessions. Intensities of 225 (R-8) and 250 microamperes (R-7) (zero to peak) were used in the experiment and post-tests. A higher intensity had been used in the pre-test for R-8 but it had to be reduced because it produced seizures when first presented in the experiment.

The experiment. Following the pre-test and deprivation to about 80% of free-feeding weight, the subjects were conditioned to key press for the 45-mg Noyes food pellets. As in Exp. I, the schedule of reinforcement was changed within six to seven sessions from FR-1 to VI-30 sec, to VI-2 min, to VI-3 min. Daily 60-min sessions were given on the VI-3 min schedule until response rates within sessions became relatively uniform. Then the subjects were started on the contingent-CS procedure in which the first response after 2 min (FI-2 min) produced the 10-sec CS. Sessions lasted for 30 CS presentations or 90 min, whichever came first. After three to six sessions with the CS alone, the ICS was presented at the end of the CS. After six ICS sessions, the food reinforcement was discontinued. During the three food-extinction sessions, ICS continued to be presented at the end of the CS but no food reinforcements were scheduled. Following these three food-extinction sessions were three more sessions with both ICS and food reinforcement. Finally, the ICS was discontinued for three sessions.

RESULTS

Figure 4 shows the reinforcing effect of the CS-UCS combination. First, it can be seen that without the UCS (ICS off), responding occurred at a relatively constant rate between CS presentations as well as during the CS. As was the case in Exp. I, this constant response rate is in contrast to the positively accelerated rate of responding between CS presentations when the UCS was added (ICS on). This fixed-interval pattern of responding was followed by a reduction in responding during the CS. Figure 4 also shows the fixed-interval pattern of responding that resulted when the UCS was present but food reinforcement discontinued (food extinction).

In this experiment, the conditioned suppression effect under the contingent-CS procedure was evaluated by food-extinction probes. Table 2 compares the response rates during the

Fig. 4. The rate of responding during the six consecutive 20-sec intervals between CS presentations and during the 10-sec CS. The response rates without the UCS (ICS off) represent averages of the three sessions immediately preceding the introduction of the UCS and the three sessions immediately after the UCS was discontinued. The response rates with both the UCS and food reinforcement (ICS on) are averages of the three sessions immediately before food extinction and the three sessions immediately after (4, 5, 6, 10, 11, 12). The response rates with the UCS but food reinforcement discontinued (food extinction) are averages of Sessions 7, 8, and 9.

Table 2

Comparison of response rates under the usual contingent-CS procedure and the contingent-CS procedure with food extinction.

	R-7		R-8	
	<i>Resp/Min Absence of CS</i>	<i>Resp/Min CS</i>	<i>Absence of CS</i>	<i>CS</i>
Contingent-CS	24.1	9.4	34.6	26.9
Contingent-CS with food extinction	10.3	5.1	23.4	31.2
Reduction resulting from food extinction	13.8	4.3	11.2	—

three food-extinction sessions with the response rates during the three preceding sessions and the three subsequent sessions under the usual contingent-CS procedure with both ICS and food reinforcement. As with the pre-feeding probes of Exp. I, it was assumed that food-extinction would reduce the rate of food-motivated responding and that the absolute amount of the reduction would be a function of the level of food-motivated responding without food-extinction. That is, if there was food-motivated responding and it was suppressed during the CS, the food-extinction probes would reduce the rate of responding and the reduction in the absence of the CS would be larger than that during the CS. As was the case with the pre-feeding probes of Exp. I, the reduction in response rate resulting from food-extinction may not indicate the absolute level of responding maintained by food because food extinction may not completely eliminate food-motivated responding. However, the reductions resulting from food extinction indicate that at least 30% (R-8) to 50% (R-7) of the responding in the absence of the CS was maintained by food. For both subjects, the effect of food-extinction was much greater in the absence of the CS than during its presence. The results of R-8 were similar to those of R-1 in Exp. I. For this subject, responding had been reduced only slightly during the CS under the usual contingent CS procedure (row 1). And, as was the case with R-1, this subject had a high response rate immediately before the CS (Fig. 4) and this rate carried over into

the early part of the CS period. The fact that extinction reduced the rate of responding in the absence of the CS but not during the CS suggests that food responding was already reduced during the CS and that the responding that remained there was being maintained by the production of the CS and the ICS rather than food.

GENERAL DISCUSSION

The present results indicate that stimuli such as conditioned reinforcers that precede an unconditioned reinforcer can have suppressive as well as reinforcing effects. Although there was no demonstration that the CS alone acquired reinforcing properties, the CS was presented in the same way that conditioned reinforcers are usually presented. It was contingent upon responding and it was temporally contiguous with a reinforcer, reinforcing brain stimulation. Yet, responding maintained by another reinforcer, food, was suppressed during the CS. This suggests that conditioned reinforcers may suppress responding which is being maintained by another reinforcer, in their presence. This effect would not be a consideration when conditioned reinforcers are very brief and/or when the only responding under consideration is that which produces the conditioned reinforcer. This effect would be a consideration in more complex situations, e.g., applied settings, where conditioned reinforcers are used to bridge substantial periods of time and other responding is being maintained by other reinforcers.

The positive conditioned suppression results are similar in several ways to negative conditioned suppression: the suppression during the CS occurs within a few pairings, it lasts over sessions, it is most evident during the CS, and it disappears soon after the UCS is discontinued. Meltzer and Brahlek (1970) showed that positive conditioned suppression is also a function of the duration of the CS and that suppression is most severe during the last half of the CS. Comparable findings with negative conditioned suppression have been obtained by Stein, Sidman, and Brady (1958) and Millenson and Hendry (1967). The present results, and those of Meltzer and Brahlek (1970), suggest another point of comparability: the suppression is largely but not entirely restricted to the CS. Several studies

of negative conditioned suppression have reported suppression in the absence of the CS (*e.g.*, Annau and Kamin, 1961; Hake and Azrin, 1965; Blackman, 1968). In the present study, this was observed for all of the subjects tested on the conventional non-contingent-CS procedure in Exp. I and for some of the subjects under the contingent-CS procedure where the addition of the UCS as a second reinforcer was expected to increase responding in the absence of the CS. It might be argued that the suppression in the absence of the CS in the Meltzer and Brahlek (1970) study was due to the use of a nutritive UCS (sucrose solution), which might have reduced deprivation and, as a result, the rate of responding for food pellets. This seems unlikely, however, in light of how infrequently the UCS was presented and in light of the present results, which were obtained with a non-nutritive UCS.

The similarities between positive and negative conditioned suppression raise the possibility that a single explanation may cover both phenomena. One explanation is that conditioned suppression results from competing responses that interfere with the ongoing baseline responding. The competing responses can be either autonomic responses or instrumental responses. For example, Azrin and Hake (1969) suggested that conditioned suppression results from a general emotional state that occurs during a stimulus paired with any strong reinforcer. This explanation is similar to that offered by Estes and Skinner (1941) to explain negative conditioned suppression, except that the interfering emotional state can result from positive as well as negative reinforcers. Autonomic changes have been found during the CS of a negative conditioned suppression procedure, *e.g.*, deToledo and Black (1966), and preceding positive reinforcers, *e.g.*, Shapiro (1961), but such changes have not been causally related to a reduction in baseline responding. The interference may also result from preparatory instrumental responses that reduce a negative reinforcer or increase a positive reinforcer. Although the delivery of aversive shock or reinforcing brain stimulation does not require a consummatory response and no preparatory responses were observed in this experiment, the possibility of preparatory instrumental responses cannot be ruled out. For example, preparatory responses to aversive shock and reinforcing brain

stimulation might involve changes in position, posture, and/or muscle tension that would increase or decrease stimulation or simply help the subject retain its balance. The fact that both reinforcing ICS (Cantor and LoLordo, 1970) and aversive shocks (Lockard, 1963) that are preceded by a signal are preferred to these stimuli alone provides some support for the preparatory response explanation, in that a signal before a stimulus allows the organism to make a preparatory response (Cantor and LoLordo, 1970).

Another explanation that may be identical to the ones above, but which is expressed only in terms of the response that is reduced would be as follows: responding decreases during the CS of a conditioned suppression procedure because after UCS is introduced, the total reinforcement during the CS is increased and, as a result, the relative reinforcing value of the baseline reinforcer is reduced, *i.e.*, relative to the total reinforcement during the CS (baseline reinforcer plus UCS). For this explanation to encompass both positive and negative conditioned suppression it must necessarily disregard the sign of the UCS. That is, when a positive or a negative UCS is introduced, the relative reinforcing value of the baseline reinforcer is reduced. The strongest support for this explanation would come from the matching function (Herrnstein, 1961) in which the relative rate of response on one operandum of concurrent schedules (Catania, 1966) or during one stimulus of a multiple schedule (Nevin, 1968) tends to match the relative rate of positive reinforcement for that operandum or that stimulus. Even though there is no response requirement for the UCS during the CS of a conditioned suppression procedure, the presentation of the UCS may still reduce the relative reinforcing value of the baseline reinforcer during the CS. The results of Pliskoff (1961, 1963), which seem similar to positive conditioned suppression, also seem to be in agreement with the matching explanation. In those experiments, responding decreased during a stimulus that was followed by a higher rate of operant reinforcement and increased during a stimulus that was followed by a lower rate of operant reinforcement. Simply, responding tended to increase or decrease during the stimulus, depending upon whether the existing or baseline rate of reinforcement was larger or smaller than that

which was to follow. All of the explanations can also explain the reduction in responding observed in the absence of the CS. For example, according to the general emotional state explanation, the emotional state would be largely but not entirely restricted to the CS. According to the explanations in terms of operant reinforcement, the addition of the UCS would reduce the reinforcement in the absence of the CS relative to the total reinforcement in the session.

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