LONG-TERM PREREWARD SUPPRESSION IN MONKEYS UNACCOMPANIED BY CARDIOVASCULAR CONDITIONING¹

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In Experiment I, a 3-min tone that preceded a free pellet of food suppressed variable-interval performances maintained by the same type of pellets, but failed to elicit conditioned changes in the heart rates and blood pressures of two rhesus monkeys. Initially severe, the prereward suppression became temporally discriminated to progressively later portions of the tone, and was maintained at an attenuated level for over four months. The suppression was apparently not caused by interfering autonomic respondents, nor was it superstitiously conditioned, since 21 of the initial 25 tone-food pairings took place outside of baseline sessions. In Experiment II, a 1-min light, paired with four free pellets of food, suppressed the variable-interval responding of a second pair of similarly trained monkeys. An interresponse-time analysis showed that in one subject, mild prereward suppression of responding developed through two stages. On early trials, response rate slowed by 10% throughout the prefood interval. On later trials, the animal suppressed by pausing for a like portion of the interval, most often near the end, but otherwise responded normally during the prefood signal.

Both prereward and preaversive stimuli have now been shown to share the property of suppressing an animal's response rate when superimposed upon certain appetitive schedules. Emotional interpretations of the disruptions occasioned by preshock warning signals have been widely held ever since the expression "conditioned anxiety" was first used by Estes and Skinner (1941) to characterize the phenomenon. It is understandable, then, that similar suggestions of an emotional etiology have recently been put forward for prereward operant disturbances (Azrin and Hake, 1969; Millenson, 1967, Ch. 18; Van Dyne, 1971).

The term "emotion" has been used with widely different meanings in writings on conditioned suppression, and on occasion has even

been left without definition to acquire the indefinite assumptions of mutual understanding. However, what appears common to a number of emotional explanations of operant respondent interactions is the proposition that suppression of operant behavior is dependent upon some internally conditioned events. For example, in the literature that speaks of preaversive suppression as fear conditioning (Kamin, 1965; McAllister and McAllister, 1971; Miller, 1951), changes in operant responding are never treated as the emotion itself, but rather as overt skeletal by-products of some normally unobserved conditioned physiological response, the latter (coupled with cognitive inferences) defining the real emotion. So described, an emotion is an intervening variable, linking certain antecedent conditions to a behavioral change. In turn, the change, suppression, is viewed as a quantitative index of the inferred emotional state, an eye on hidden events. These internal physiological responses are held to have been incompatible with, hence to have interfered with, the subject's skeletal activities during the preshock stimulus, resulting in a decrease in operant work.

A similarly reasoned emotional interference hypothesis has been proposed by Azrin and Hake (1969) to account for the suppressant properties of prereward stimuli. Noting dur-

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ing prereward signals that different subjects engaged in different activities including running, hovering, and just standing still, Azrin and Hake concluded that suppression of the trained operant could not be attributed to competition from incompatible operants. Instead, they proposed that responding was impaired by a "general emotional state" resulting from the presentation of a stimulus (CS) paired with a strong reinforcer (US), in this case, a positive reinforcer. They further suggested that the prereward emotional state was probably associated with autonomic changes like those reported to condition to preshock stimuli, which also suppress operant behavior (Brady, Kelly, and Plumlee, 1969, de Toledo and Black, 1966; Parrish, 1967; Stebbins and Smith, 1964). Van Dyne (1971) concurred with the hypothesis that prereward suppression might reflect interference by autonomic conditioned responses, but has disagreed with the undifferentiated quality of Azrin and Hake's proposed pre-US emotional state. Van Dyne suggests that prereward respondents probably differ from preaversive respondents, sharing only the common property of being incompatible with operant responding. Neither proposal, however, explains comfortably how a normally incapacitating set of prereward respondents can result in reliable acceleration of DRL performance (Herrnstein and Morse, 1957; Henton and Brady, 1970) and in acceleration of variable-interval performance during long duration CSs (Meltzer and Brahlek, 1970). An interference hypothesis is virtually constrained to identify suppression as *the* behavioral effect of prereward stimuli and to argue that other forms of prereward disruptions are probably the spurious results of accidental correlations between the non-contingent US and the operant response.

Experiment I recorded concurrent cardiovascular responses in two monkeys during the acquisition and long-term maintenance of prereward suppression of variable-interval responding. In Experiment II, the prefood suppression observed in Experiment I was extended to a second pair of monkeys, using a briefer duration, different-modality CS that was followed by a more substantial amount of free food than in the first experiment. In addition, the acquisition of prereward suppression by one monkey was submitted to an inter-response-time analysis.

EXPERIMENT I

METHOD

Subjects

Two experimentally naive adolescent male rhesus monkeys (*Macaca mulatta*) were studied. Monkey A weighed 4.5 kg and Monkey B, 5.4 kg at the start of the experiment.

Apparatus

Each monkey was permanently restrained in a Plexiglas primate chair enclosed within an individual sound-attenuating booth. A response lever was mounted upon the waistplate of the chair, 15 cm (6 in.) directly in front of the monkey. The lever could be activated by exerting a dead-weight force of 275 to 330 g through a 1.5-cm (0.75 in.) excursion, a total minimum work requirement of approximately 44×10^4 ergs (0.044 J). Water was available to the monkey at all times, and was delivered in 0.75-sec squirts of 5 ml each through a spout mounted 10 cm (4 in.) to the left of its head. The monkey could obtain the water by pressing a nose-key located next to the spout, on a one press, one squirt, basis. Aside from one piece of fruit offered three times a week, all the monkey's food was earned during the experimental sessions in the form of Dietrich and Gambrill 750-mg whole diet pellets. They were delivered through a chute located opposite the water spout, and a 1-sec tone feedback accompanied every pellet dispenser operation. The main houselight was a 6-W fluorescent bulb mounted on the rear wall directly behind the subject's head. Adjacent to the houselight was a 3-ohm speaker used to present the CS, a 600-Hz pure tone. Twenty-four hour behavioral scheduling and recording was accomplished with a mixture of relay and transistor equipment located in an adjacent room.

Autonomic recording. Each monkey was implanted with a chronic femoral artery catheter for continuous monitoring of heart rate and blood pressure. Details of the preparation were similar to those described by Brady, Kelly, and Plumlee (1969). Blood pressure recordings were obtained with a Sanborn strain-gauge transducer and two-channel recorder. An amplified electrical signal that paralleled the pressure wave was fed to a solid-state level detector, which triggered upon each heart beat

(Swinnen, 1967). The heart beat impulses were accumulated and printed out at 1-min intervals synchronized with the scheduled behavioral events. Systolic and diastolic blood pressure levels for the same minutes were calculated from the polygraph records with the help of a clear plastic overlay. Ten readings at 6-sec intervals were averaged each minute.

Procedure

Behavioral baseline. Initially, every lever press produced a pellet of food. The acquisition of this response required no shaping. After three to five days, the availability of food was restricted to two 1-hr periods each day that were signalled by turning off the main house-lights. Thereafter, a schedule of two 1-hr sessions per day, the first from 9 to 10 a.m. and the second from 5 to 6 p.m., remained in effect seven days per week throughout the experiment.

Each monkey was then exposed to an extended series of progressively more intermittent random-ratio schedules, which specified a given uniform probability of reinforcement for every response. Reinforcement probability was decreased in blocks of five sessions each from 1.0 (continuous reinforcement) to 0.5, 0.3, 0.2, 0.1, 0.07, 0.03, 0.02, and 0.01. The monkeys then were switched to a variable-interval 1-min, limited-hold 7.5-sec schedule (VI 1-min LH 7.5-sec) and given 35 sessions. The limited-hold contingency required that the subject respond within 7.5 sec after a reinforcement was scheduled by the variable-interval timer or that opportunity was lost. On this schedule, each subject earned a daily subsistence diet of 105 to 115 pellets, or roughly 475 Kcal per day, excluding fruit supplements and the non-contingent reinforcers scheduled as part of the Pavlovian pairings.

Pavlovian pairings. Both monkeys were first exposed to the pure tone that was to serve as the CS in a series of 20, 3-min presentations, half taking place during experimental sessions (one per session), half at midday in between sessions (two per day). When the CS alone no longer produced changes in heart rate, blood pressure, and lever pressing, the CS-US pairings were inaugurated. Twenty-one of the first 25 Pavlovian pairings occurred outside the food sessions to avoid adventitious correlation between the US and lever pressing. On

the first three days, pairings 1 to 7, 10 to 16, and 19 to 25 took place midway between the two daily sessions. These off-the-baseline trials were spaced 5 min apart. Otherwise, the CS was presented only once during the thirtieth minute of each 1-hr session and was terminated 3 min later with one free food pellet (US) of the same sort used to reinforce the baseline performance. To ensure independence of autonomic responses, which might be conditioned to successive tone-food pairings, only one pairing was scheduled per session. The CS-US pairings continued twice per day for 127 days, or a total of 275 pairings, counting the 21 that took place off the baseline.

Timeout periods. In addition to the CS, a second 3-min stimulus also occurred during each session. From the twenty-first to twenty-fourth min, or 9 min before the prereward CS, the main houselight in the darkened work chamber was turned on (this was also the inter-session stimulus), and food reinforcement was suspended. The light was therefore a discriminated-extinction, or timeout stimulus and was meant to control for the cardiovascular consequences of abrupt changes in the monkey's lever-pressing activities.

RESULTS

The initial effect of the CS, previously paired off-the-baseline with food, was to suppress the responding of both monkeys severely and consistently for at least 25 trials. With repeated, paired presentations over the course of several months, the severity of the suppression eventually attenuated, and was no longer observed on every trial. However, some reliable suppression, albeit reduced and intermittent, persisted for the 18-week term of the experiment. By contrast, at no time did any cardiovascular responses appear to condition to the tone-food pairings.

Behavioral effects. Figure 1 presents both subjects' minute-by-minute behavioral and cardiovascular responses for the final two adaptation trials, the first six individual baseline trials and then for blocks of 25 trials thereafter. The "per cent change" measure of response rate during the CS is arithmetically identical, except for the decimal point, to the inflection ratio of Hunt, Jernberg, and Brady (1952), $b-a/a$, where a = pre-CS control rate, and b = CS rate. One important behavioral finding is the immediacy with which the pre-

food signal came to suppress both subjects' operant performances. Despite thorough adaptation to the tone before Pavlovian condition-

ing, Monkey A (upper half) slowed its responding during the initial minute of the first baseline trial (Pairing 8) by 80% from its pre-

Fig. 1. Minute-by-minute changes in the blood pressure, heart rates, and variable-interval response rates of two monkeys during 275 successive 3-min tone-food pairings. The last two adaptation trials and the first six baseline trials are presented individually to the left of the dashed vertical line. To the right, data are averaged $\pm$ one standard deviation in blocks of 25 ending with the trial indicated. $N = 29$ in the first block through Trial 50. At the arrows, three sets of seven tone-food pairings were presented at midday, in between the two daily operant sessions. The zero point on each ordinate scale represents a control value calculated from the 3-min immediately preceding the tone.

CS control rate and stopped completely during the last minute. Monkey B (lower half) showed a similarly severe suppression during the first baseline trial, except that it pressed the lever 12 times during the final CS minute, as compared with its control rate of 63 responses per minute. Since no non-contingent food pellets had yet been presented during operant sessions, the suppression on Trial 8 must have been related to those signal properties that were conditioned to the CS during the seven preceding off-the-baseline trials, and not to an adventitious correlation between a pause in responding and a free reinforcer.

The rapidly conditioned prereward suppression proved to be an enduring phenomenon as well in both animals. Monkey A's overall response rate during the CS was lower than in the pre-CS control period on the first 41 straight baseline trials. Thereafter, even when overall rate in the CS was not suppressed, responding during the third CS minute was consistently lower than control rates. In fact, during the final three months of the experiment, this subject showed a reliable acceleration of responding during the first CS minute followed by a progressive decline in rate through the final 2 min. Monkey B showed suppressed responding on its first 24 consecutive baseline trials and, as shown in the lower half of Figure 1, also suppressed most severely during the terminal prefood minute.

Pre-CS control rates are presented in Table 1 for both subjects, along with the correspond-

ing mean CS rate change and the relative incidence of suppression observed in blocks of 25 trials. As the term is used here, suppression refers to a 3-min CS rate that was lower than its control on a given trial. Noteworthy in these data is the evidence that even though the severity of suppression during the full 3-min CS relented noticeably for both subjects over the sessions, some conditioned suppression occurred reliably throughout the experiment. Sixty four of Monkey A's last 100 trials showed lower CS than control response rates. Monkey B suppressed, if only slightly, on 74 of the last 100 trials.

The gradual attenuation of suppression noted in Figure 1 reflected not so much an overall loss in stimulus control as a shift in the pattern of suppression from throughout the CS to a progressively more compact period immediately preceding the US. Figure 2 illustrates the development of this pattern in Monkey A's cumulative records drawn from six round-number trials from the eighth to two hundred and fiftieth CS-US pairing. During the first baseline trial (leftmost record), Monkey A's responding was suppressed throughout the CS. By the fiftieth trial, the next shown, responding continued at a normal pace for approximately 40 sec into the CS, earning the monkey two reinforcements (upward deflections). Responding then ceased until the free pellet was delivered. On the succeeding trials illustrated in Figure 2, Monkey A slackened its responding at progressively

Table 1
Baseline Rates of Responding and Severity and Incidence of CS Rate Changes

Pairings	Monkey A			Monkey B		
	Baseline Response Rate $\pm$ sd	Mean Per Cent Rate Change in CS	Per Cent Trials Showing Suppression ^a	Baseline Response Rate $\pm$ sd	Mean Per Cent Rate Change in CS	Per Cent Trials Showing Suppression ^a
1-50 ^b	29 $\pm$ 6.1	-52.5%	100%	55 $\pm$ 3.1	-29.5%	97%
51-75	38 $\pm$ 4.0	-46.3	92	55 $\pm$ 12.1	-17.0	84
76-100	43 $\pm$ 3.6	-26.3	84	55 $\pm$ 4.9	- 6.8	64
101-125	44 $\pm$ 10.6	-12.6	76	58 $\pm$ 2.7	-19.2	76
126-150	46 $\pm$ 6.7	- 3.3	60	60 $\pm$ 4.1	- 2.0	56
151-175	28 $\pm$ 11.0	- 3.4	64	51 $\pm$ 9.0	- 4.1	52
176-200	49 $\pm$ 3.8	- 7.6	64	32 $\pm$ 8.8	0	44
201-225	42 $\pm$ 5.5	+ 7.8	44	27 $\pm$ 4.7	- 8.1	76
226-250	33 $\pm$ 9.4	-10.0	72	28 $\pm$ 7.2	-10.8	84
251-275	31 $\pm$ 6.8	- 2.0	76	29 $\pm$ 7.6	- 8.3	92

^aSuppression defined as a lower CS than control rate

^bn = 29 on-the-baseline CS-US pairings

Fig. 2. Cumulative records showing the development of a progressively finer temporal discrimination in Monkey A's responding during selected tone-food pairings, as numbered. Trial 8 represents the first trial on the baseline. Trial 250 occurred 115 days later, 13 days from the end of the experiment. Each record is 10 min in length and is centered on the 3-min CS. Baseline reinforcers are indicated by downward deflections except during the CS, when they appear as upward deflections. The pen is offset through the CS. A single non-contingent food pellet (US) was delivered at the arrows.

later points in the CS until 116 days later, during the two hundred and fiftieth trial, there was evidence of only a slight slowdown in rate, restricted to the several seconds before the US.

Autonomic responses. In contrast to the strong cardiovascular responses that have been found to condition to preaversive stimuli, the prereward pairings failed to elicit any consistent change in heart rate, systolic, or diastolic blood pressure. Anticipatory autonomic conditioning failed to develop despite 275 tone-food pairings, and despite the same CS's notable effectiveness in suppressing responding. As compared to a preshock warning stimulus, the autonomic inconsequence of the prefood signal for monkeys did not corroborate on a physiological level the strong similarities in the be-

havioral effects of these signals, even as regards the time course in acquisition, maintenance, and the temporally discriminated pattern of the operant suppression occasioned by both in monkeys. In Figure 1, the minute-by-minute changes in heart rate and systolic blood pressure are plotted above the behavioral data for the same trials. Since Brady *et al.* (1969) found that diastolic blood pressure variations tended to lag sluggishly behind the conditioned stimuli or activity alterations that prompted them, only systolic blood pressure has been plotted. However, the diastolic measurements confirmed the inconsistent and minor prefood variations in the systolic pressure.

The control heart rates and blood pressures of both subjects remained well within the normal range for chaired rhesus monkeys

(Stahl and Malinow, 1967; Whitney, Johnson, and Cole, 1967). Monkey A's mean control heart rate throughout the 20-week experiment, including adaptation sessions, was 202.8 beats per minute with a standard deviation of ± 21.0 . Monkey B's was 168.9 ± 25.6 beats per minute. These data were also within the control range of heart rates of the five monkeys that showed conditioned autonomic responses to aversive CSs, as reported by Brady *et al.* (1969). Thus, it is not likely that the failure of the animals to develop conditioned cardiovascular responses during positive Pavlovian pairings can be explained by any pathologic hyper- or hypotensive condition.

Timeout periods. Most likely as the result of a strong light-dark discrimination established during an earlier experiment, neither monkey made a single timeout response throughout the experiment. The effects noted during the present study did not differ from those described for timeout stimuli by Brady *et al.* (1969) and thus are not repeated in detail in this report. In brief, heart rate and blood pressure declined in both subjects during timeout periods; however, these cardiovascular effects, as in the earlier experiment, appeared to be incidental to the abrupt drop in the subject's somatic activity represented by a complete cessation of lever pressing. Removing the response levers from the chambers and repeating the light-dark cycles of the session and timeout stimuli produced no cardiovascular fluctuations.

EXPERIMENT II

Prereward studies upon primates have been few, and, perhaps because of widely different procedures, they have not as yet produced a clear-cut pattern of interactions. Henton and Brady (1970) described two rhesus monkeys that showed accelerated DRL responding during an 80-sec visual prefood stimulus, but no changes at shorter CS durations. Studying two New World squirrel monkeys (*Saimiri sciureus*) Miczek and Grossman (1971) found suppression of variable-interval responding during prereward stimuli of 30 sec or less, but no effects with longer durations of the order used in Experiment I. Because Experiment I involved only two subjects and because they represented the only Old World monkeys in which prereward suppression had been found, the reliability of that result was tested in a second

pair of similarly trained but uncatheterized subjects. Several parameters of the CS-US pairings were changed to determine if any of these had been critical to the suppressant properties developed by the CS in Experiment I: the CS was visual rather than auditory, was presented for a shorter duration, and was followed by a more substantial noncontingent reinforcement. Also, the CS alone was not pre-exposed to the subjects before pairings with the US, a practice followed in Experiment I and which has been found in the preaversive case to interfere mildly with the subsequent acquisition of suppression (May, Tolman, and Schoenfeldt, 1967; Rescorla, 1971).

METHOD

Subjects

Two naive male rhesus monkeys were studied. Monkey C weighed 7.70 kg and Monkey D, 5.14 kg at the start of the experiment.

Apparatus

The experimental chambers were identical to those used in Experiment I except that, to serve as the CS, a red jewelled panel light was mounted 22 cm (8.75 in.) directly in front of the monkey's face.

Procedure

All details of the baseline training, experimental diet, and supplementary feedings of the monkeys were identical to Experiment I, except the monkeys were not catheterized for autonomic recordings.

CS-US pairings. Neither monkey was adapted to the CS before pairings with the US, and all pairings were carried out during baseline sessions. The CS was a 1-min flashing red light (1 sec on, 1 sec off) that was paired terminally with four food pellets. The CS was presented three times, during the tenth, twenty-fifth, and fortieth minutes of each session. As a result, the subject received 12 noncontingent pellets each session, which were in excess of the 52 to 57 normally earned during VI performance. The pairings continued three per session, two sessions per day, for 25 days—a total of 150 pairings. There was no timeout condition.

RESULTS

Monkeys C and D also developed temporally discriminated suppressed patterns of respond-

ing during the prereward CS. Without the benefit of the 21 off-the-baseline pairings arranged for Monkeys A and B, the present subjects' suppression initially developed more slowly across an equivalent number of on-the-baseline trials. However, by the final stages of the experiment, both the severity and incidence of behavioral suppression appeared to be at least equivalent to that attained at a comparable stage in Experiment I.

Figure 3 plots the changes in CS responding of both monkeys over the 150 trials. Closed circles show the per cent rate change during the CS and refer to the left axes. Open triangles refer to the right axes and reflect the relative incidence of suppression defined as any trial showing a lower-than-control rate. The development of suppression followed different patterns in the two subjects. On early trials, Monkey C responded at or above control rates, but as the experiment progressed it displayed a systematic trend toward both more frequent and more severe CS suppression. Ultimately, Monkey C suppressed on all of the

last 25 trials with an average per cent change of -40% . The negative sloped (-0.38) straight line in Figure 3 (upper half) was fit to these data by the method of averages. On the other hand, Monkey D (lower half) suppressed less severely but more consistently throughout the 150 trials. This subject showed suppressed responding on 21 of the final 25 CS presentations, but its average CS rate change was only -9% . The slope constant of the nearly horizontal function fit to Monkey D's rate change data is 0.062.

As in Experiment I, the prereward suppression of both subjects tended with passing trials to become restricted to a progressively later period within the CS. The development of this pattern in Monkey D was accompanied by corroborating changes in the distribution of its interresponse times (IRTs); IRTs were collected separately for pre-CS and CS periods and were sorted into eighteen 250-msec bins covering a range of 4.5 sec. Longer IRTs were recorded collectively as "pauses". Figure 4 shows that as Monkey D gained experience with the 1-min CS interval, the IRT composition of its CS responding shifted without changing in overall suppression level (approximately -10%). Suppression on early trials was characterized by a frequency shift in all IRT categories relative to control distributions; later suppression appeared as a shift only in long pauses (IRTs $>$ than 4.5 sec and coded as "P" in Figure 4). In the top row of Figure 4 covering the first 27 trials, IRTs during the CS (dashed lines) were uniformly shifted to the right of control IRTs (solid lines) by one 0.25-sec bin. This indicates that on early trials, the subject actually responded more slowly than normal during the CS and that suppression was not produced simply by more frequent or longer pauses. However, on later trials shown in the middle and bottom rows of Figure 4, CS distributions closely resembled control distributions except for height (i.e., the proportion of IRTs $<$ 4.5 sec), otherwise sharing the same shape and usually the same modal IRT. Thus, on these trials Monkey D did appear to suppress primarily by pausing. Further, since there was no increase during the CS in the frequency of pauses, it appears that on these later trials Monkey D must have paused longer, when it paused, but responded normally when it responded. In sum, early in its experience with the CS, Mon-

Fig. 3. Severity and incidence of prereward suppression over 150 trials. The filled circles represent the average rate change during the CS in blocks of 10 trials. Open triangles reflect the relative incidence of suppression in blocks of 25 trials. Suppression was defined as an individual trial when the CS rate was lower than the preceding control.

Fig. 4. Interresponse-time distributions for selected blocks of nine trials, each comparing Monkey D's responding during the CS (dashed functions) to the immediately preceding control intervals (solid). IRTs were recorded in 0.25-sec categories up to 4.5 sec maximum. Longer IRTs are plotted separately as pauses (P).

key D showed slower local rates of CS responding that averaged 10% below control rates; later, suppression was restricted to longer, but not more frequent, pauses that produced the same net effect.

GENERAL DISCUSSION

The principal finding in both experiments was that monkeys suppressed variable-interval responding for food pellets in anticipation of non-contingent samples of the same. The phenomenon, which replicates Azrin and Hake's (1969) and Van Dyne's (1971) findings in rats, also proved durable, lasting 4 to 5 months, and, like preaversive suppression, became temporally discriminated to later portions of the CS. The direction of the prereward interaction appeared not to depend critically upon the modality of the CS, its pre-exposure, or

whether initial CS-US pairings were carried out during or in between operant sessions. The suppression was not superstitious, nor was it associated with any conditioned cardiovascular respondents.

Several investigators have already commented upon the similarities between this type of positive conditioned suppression, as it was called by Azrin and Hake (1969), and that produced by preaversive warning signals. Besides widespread suppressant properties, both prereward and preaversive stimuli have been found to require a comparable number of trials for conditioning and for extinction (Azrin and Hake, 1969) and to share such common parameters as CS duration (Meltzer and Brahlek, 1970), US magnitude (Azrin and Hake, 1969), and possibly the ratio of CS-on-to-off time (Henton and Brady, 1970). To this list may be added the detailed observation from

the present experiment that the habituation of prereward suppression over trials linked with a developing pattern of temporal discrimination within the prereward interval closely resembles the evolution of similar properties of fixed-duration preshock stimuli (Hendry and Van Toller, 1965; Millenson and Hendry, 1967). Even the unexplained acceleration immediately after CS onset during later trials, evidenced in Monkey A's prereward responding in Figure 1 (see trials 175 to 225), finds a detailed parallel in the late-session preaversive data presented by Millenson and Hendry (1967, see their Figure 2).

In light of the many empirical similarities between the behavioral effects of prereward and preaversive stimuli, the clear contrast in the autonomic effects conditionable to each is surprising, particularly since it has sometimes been assumed that such respondents are involved in producing the operant effects. Although changes in heart rate, respiration, and systolic and diastolic blood pressure have been known to condition to preshock suppressive stimuli, no conditioned autonomic responses were observed in the present Experiment I during either acquisition or prolonged maintenance of prereward suppression. This negative finding has been confirmed in a second study involving three additional rhesus monkeys (Kelly, 1971).

It seems likely now that conditioned autonomic responses play a role in neither prereward nor preaversive suppression of operant behaviors. A number of recent findings involving both positive and negative Pavlovian paradigms seem to undermine the interference hypothesis, at least that version of it that identifies the interfering respondents as autonomic responses. First, it appears that monkeys accelerate their heart rates and increase their blood pressures during stimuli that predict shock (Brady *et al.*, 1969; Kelly, 1971; Stebbins and Smith, 1964; Zeiner, Nathan, and Smith, 1969), while rats (de Toledo, 1971; de Toledo and Black, 1966; Parrish, 1967) and rabbits (Swadlow, Hosking, and Schneiderman, 1971) decelerate their cardiac rates. Nevertheless, the same Pavlovian stimuli suppress the operant responding of all three species.

Second, if one reviews on a trial-by-trial basis the relative pace with which behavioral suppression and autonomic responses condition to preaversive stimuli, invariably oper-

ant suppression is found to condition with fewer CS-US pairings than the autonomic conditioned responses. Brady *et al.* (1969) showed that after only a few pairings with severe shock, a 3-min auditory CS completely suppressed the variable-interval performances of five monkeys, but had no conditioned effects upon their cardiovascular system. The latter appeared only after extended CS-US pairings. Similarly slow cardiac acquisition rates during formation of a conditioned emotional response (CER) have been reported in rats by de Toledo and Black (1966) and by Parrish (1967). In fact, only when early CS-US pairings have been presented outside of operant baseline performances, effectively allowing autonomic responses to condition before operant suppression is tested, has the development of preaversive respondents appeared to parallel the acquisition of suppression (Zeiner *et al.*, 1969). Brady *et al.* further reported that suppression was also more rapidly extinguished than autonomic responses when shock was no longer paired with the CS. Since the behavioral and cardiovascular responses to preshock stimuli appear to be completely dissociable, in all likelihood, they are causally unrelated. The present experiment further suggests that the same is probably true for the prereward paradigm.

Third, even if the empirical correlation of conditioned respondents to operant suppression were perfect, there is no satisfactory explanation as to how such respondents might render an animal incapable of pressing a lever. The early descriptions by Hunt and Brady (1951) and others of albino rats apparently paralyzed with fear during preshock stimuli, crouching, urinating, *etc.*, seem to have had an unusually strong influence upon subsequent interpretations of conditioned suppression. Yet this behavioral pattern, intuitively associated with extreme fright, is typically limited to early CS presentations and generally attenuates well before suppression of operant behavior itself becomes habituated or temporally discriminated (Millenson and Dent, 1971). Also, an early trial pattern of freezing, though occasionally observed in species other than the rat, is definitely not the norm for such subjects as cats (personal observations), guinea pigs (Valenstein, 1959) and particularly Old World monkeys (Henton, Salzberg, and Jordan, 1969), as evidenced by above normal CS rates noted

in various unprogrammed behaviors. For instance, though not previously reported by Brady *et al.* (1969), two subjects, Monkeys A and E, in that experiment were observed routinely during periods of preshock suppression to chew and swallow contingently earned pellets they had stored in their cheek pouches. Though the monkeys did not respond for new food during the 3-min CS, they consumed previously acquired pellets and worked as well for prandial drinks. Still, these subjects displayed patterns of preaversive suppression very similar to the other, non-pouch-storing monkeys in the study. Indeed, it appears that while some rats may "freeze" when warned of an impending shock, most animals, even if autonomically upset, probably remain capable of performing the reinforced operant.

In light of the present data, the evidence may appear even more slight for the proposition that interfering respondents play an important role in prereward interactions. Yet, the emotional nature of prereward behavioral disturbances already appears to have earned wide acceptance on intuitive grounds. The terms "joy", "elation", "pleasure", "euphoria", and even "hope" have been proposed emphatically to characterize the emotional state thought to account for a subject's erratic prereward performance (Azrin and Hake, 1969; Bull, 1970; Millenson, 1967). Recently, Hake and Powell (1970) attempted an explanation of prereward suppression phrased only in terms of the operant that is reduced during the CS and which postulates no additional learned behaviors, operant or respondent. They suggest that CS responding declines because, through addition of the US, total reinforcement becomes higher during CS than non-CS periods. Contingent reinforcements account for all reinforcements in the non-CS condition, but for only some of the reinforcements occurring during the CS. Thus, they argue, the relative reinforcing value of the baseline reinforcer decreases, and with it, response rate, consistent with the matching function for concurrent operants (Herrnstein, 1961). However, this explanation would seem to predict that if all CS-US pairings occurred off-the-baseline and if the US was never presented during an operant session, there should be no rate changes during continued baseline presentations of the CS alone, since there would be no change in total reinforcements during the CS

(except for secondary reinforcing properties that might be acquired by the CS). Yet this procedure produces suppression (Van Dyne, 1971). Also it may not be empirically correct to assume that total reinforcements are necessarily greater during CS than non-CS periods. In the case where the US is small in magnitude and is identical to the baseline reinforcer, as in the present Experiment I, consistent CS suppression of the severity shown by Monkeys A and B on early trials might result in lower reinforcement rates in CS relative to non-CS periods, or in other words, in more contingent reinforcements being missed than would be replaced by the US.

An alternative interpretation of prereward suppression might be formulated in terms of effort or response cost. Relative to the work required to obtain contingent baseline reinforcements, no effort beyond seizing and consummatory behaviors is required of the subject to obtain the non-contingent US. When reinforcing brain stimulation is used as the US, not even consummatory responses are required (Azrin and Hake, 1969; Hake and Powell, 1970; Van Dyne, 1971). Prereward suppression then, instead of reflecting a decline in the relative reinforcing value of the baseline reinforcer, might represent a shift in the amount of work a subject will perform to obtain baseline reinforcements, a criterion shift in effort. Prereward pairings offer something for nothing. Their superimposition upon any contingent schedule temporarily changes the total work required of the subject to produce a basal level of reinforcement. In colloquial terms, this is a why-work-when-you-can-get-it-for-nothing suggestion. If it is accepted that experimenters are sometimes disinclined to work or exert themselves, perhaps the same is true for subjects.

REFERENCES

- Azrin, N. H. and Hake, D. F. Positive conditioned suppression: conditioned suppression using positive reinforcers as the unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 167-173.
- Brady, J. V., Kelly, D. D., and Plumlee, L. Autonomic and behavioral responses of the rhesus monkey to emotional conditioning. *Annals of the New York Academy of Sciences*, 1969, 159, Article 3, 959-975.
- Bull, J. A., III. An interaction between appetitive Pavlovian CSs and instrumental avoidance responding. *Learning and Motivation*, 1970, 1, 18-26.

- de Toledo, L. Changes in heart rate during conditioned suppression in rats as a function of US intensity and type of CS. *Journal of Comparative and Physiological Psychology*, 1971, 77, 528-538.
- de Toledo, L. and Black, A. H. Heart rate: Changes during conditioned suppression in rats. *Science*, 1966, 152, 1404-1406.
- Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *Journal of Experimental Psychology*, 1941, 29, 390-400.
- Hake, D. F. and Powell, J. Positive reinforcement and suppression from the same occurrence of the unconditioned stimulus in a positive conditioned suppression procedure. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 247-257.
- Hendry, D. P. and Van Toller, C. Alleviation of conditioned suppression. *Journal of Comparative and Physiological Psychology*, 1965, 49, 458-460.
- Henton, W. W. and Brady, J. V. Operant acceleration during a pre-reward stimulus. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 205-209.
- Henton, W. W., Salzberg, C. L., and Jordan, J. J. Conditioned suppression and acceleration of two concurrent responses in rhesus monkeys. *Psychological Reports*, 1969, 24, 375-387.
- Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 267-272.
- Herrnstein, R. J. and Morse, W. H. Some effects of response independent positive reinforcement on maintained operant behavior. *Journal of Comparative and Physiological Psychology*, 1957, 50, 461-467.
- Hunt, H. F. and Brady, J. V. Some effects of electroconvulsive shock on a conditioned emotional response ("anxiety"). *Journal of Comparative and Physiological Psychology*, 1951, 44, 88-98.
- Hunt, H. F., Jernberg, P., and Brady, J. V. The effect of electroconvulsive shock (ECS) on a conditioned emotional response: The effect of post-ECS extinction on the reappearance of the response. *Journal of Comparative and Physiological Psychology*, 1952, 45, 589-599.
- Kamin, L. J. Temporal and intensity characteristics of the conditioned stimulus. In W. F. Prokasy (Ed.), *Classical conditioning*. New York: Appleton-Century-Crofts, 1965. Pp. 118-147.
- Kelly, D. D. *The contrasting cardiovascular consequences of monkeying around with conditioned anxiety, conditioned elation and discriminated extinction*. Paper presented at the annual meeting of the Eastern Psychological Association, New York, April 1971.
- May, R. B., Tolman, C. W., and Schoenfeldt, M. G. Effects of pre-training exposure to the CS on conditioned suppression. *Psychonomic Science*, 1967, 9, 61-62.
- McAllister, W. R. and McAllister, D. E. Behavioral measurement of conditioned fear. In F. R. Brush (Ed.), *Aversive conditioning and learning*. New York: Academic Press, 1971. Pp. 105-179.
- Meltzer, D. and Brahlek, J. A. Conditioned suppression and conditioned enhancement with the same positive UCS: an effect of CS duration. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 67-73.
- Miczek, K. A. and Grossman, S. P. Positive conditioned suppression: effects of CS duration. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 243-247.
- Millenson, J. R. *Principles of behavioral analysis*. New York: Macmillan, 1967.
- Millenson, J. R. and Dent, J. G. Habituation of conditioned suppression. *Quarterly Journal of Experimental Psychology*, 1971, 23, 126-134.
- Millenson, J. R. and Hendry, D. P. Quantification of response suppression in conditioned anxiety training. *Canadian Journal of Psychology*, 1967, 21, 242-252.
- Miller, N. E. Learnable drives and rewards. In S. S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951. Pp. 435-472.
- Parrish, J. Classical discrimination conditioning of heart rate and bar-press suppression in rats. *Psychonomic Science*, 1967, 9, 267-268.
- Rescorla, R. A. Summation and retardation tests of latent inhibition. *Journal of Comparative and Physiological Psychology*, 1971, 75, 77-81.
- Stahl, W. R. and Malinow, W. R. A survey of physiological measurements in *Macaca mulatta*. *Folia Primatologica*, 1967, 7, 12-33.
- Stebbins, W. and Smith, O. A., Jr. Cardiovascular concomitants of the conditioned emotional response in the monkey. *Science*, 1964, 144, 881-883.
- Swadlow, H. A., Hosking, K. E., and Schneiderman, N. Differential heart rate conditioning and lever lift suppression in restrained rabbits. *Physiology and Behavior*, 1971, 7, 257-260.
- Swinnen, M. An inexpensive level detector. *Psychophysiology*, 1967, 3, 318-320.
- Valenstein, E. S. The effect of reserpine on the conditioned emotional response in the guinea pig. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 219-225.
- Van Dyne, G. Conditioned suppression with a positive US in the rat. *Journal of Comparative and Physiological Psychology*, 1971, 77, 131-135.
- Whitney, R. A., Johnson, D. J., and Cole, W. C. *The subhuman primate: a guide for the veterinarian*. Technical Report No. EASP 100-26, Medical Research Laboratories, Edgewood Arsenal, Maryland, 1967.
- Zeiner, A. R., Nathan, M., and Smith, O. A., Jr. Conditioned emotional responding (CER) mediated by interference. *Physiology and Behavior*, 1969, 4, 645-648.

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