**CONDITIONAL ACCELERATION AND EXTERNAL
DISINHIBITION OF OPERANT LEVER PRESSING
BY PREREWARD, NEUTRAL, AND
REINFORCING STIMULI**

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Rats responding under a differential-reinforcement-of-low-rate schedule increased their rates of lever pressing during a 20-second click/flash stimulus that preceded the delivery of a response-independent food pellet. The increase could not be attributed to suppression of collateral behavior that has been said to mediate temporally-spaced responding. We propose that the prereward stimulus functioned as an external disinhibitor of lever pressing that had been inhibited by the constraints of the operant schedule. Support is derived from the observed disinhibitory effects of a 10-second unpaired click/flash stimulus and of unsignaled, response-independent pellets that were presented while the animals were responding under the same schedule.

Key words: conditional acceleration, response-independent reinforcement, disinhibition, collateral behavior, differential-reinforcement-of-low-rate, lever press, rats

When prefood or preshock stimuli are presented to an animal that is engaged in operant responding, the animal's rate of responding often shows sharp changes. The most frequently observed outcome is a decrease in rate of responding (conditional suppression). However, when responding is maintained by a differential-reinforcement-of-low rate (DRL) schedule, conditional acceleration is frequently observed. For example, Henton and Brady (1970) found that rhesus monkeys responded more rapidly under DRL schedules during a prefood stimulus. Kelly (1973) also found conditional acceleration in rhesus monkeys under similar conditions. However, when the same monkeys were exposed to the prefood stimulus while responding under a random-ratio (RR) schedule, response rate during the signal decreased. Blackman (1968) reported acceleration of DRL performance in rats during a preaversive stimulus and suppression of fixed-interval,

limited-hold behavior during the same stimulus.

In addition to being an infrequently reported outcome, conditional acceleration of DRL performance is somewhat surprising since it can result in a loss of reinforcers under the operant schedule. An alternate suggestion has been made by Blackman and by Henton and Brady, who proposed that prefood or preshock stimuli disrupt or suppress the collateral responses that typically occur under DRL schedules. If, as several investigators (Laties, Weiss, & Weiss, 1969; Wilson & Keller, 1953) have proposed, collateral behavior serves a mediating or timing function, then its disruption might be expected to increase rate of operant responding. We investigated this hypothesis by exposing rats to a prefood stimulus superimposed on a DRL schedule while recording operant lever presses and several collateral activities (running, drinking, and wood chewing). We wanted to determine if the effect of the prefood or conditional stimulus (CS) on operant responding depended upon what the animal was doing at its onset. If, as Blackman and Henton and Brady suggest, acceleration of DRL responding results from disruption of mediating behavior, then acceleration would be most likely when the animal was engaged in such behavior. Acceleration would be less likely if the

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animal were engaged in lever pressing or some other nonmediating behavior at CS onset.

One drawback of the collateral-response hypothesis is the lack of direct empirical support for the notion that collateral behavior does, in fact, mediate DRL performance (cf., Hemmes, Eckerman, & Rubinsky, 1979; Smith & Clark, 1974). For this reason, we evaluated an alternative analysis of conditional acceleration of DRL responding. In this analysis, the CS is considered to be an unconditional (i.e., unlearned) disinhibitor of operant responding. Brimer (1972) and others have noted that rate of an operant response can be altered by noncontingent presentations of extraneous novel stimuli. Generally, rate of maintained responding decreases during the stimuli (Deluty, 1976; Hearst, Franklin, & Mueller, 1974); however, when responding is already depressed by the operant contingency, acceleration is likely (e.g., Boakes & Halliday, 1975; Brimer & Kamin, 1963; Contrucci, Hothersall, & Wickens, 1971; DeNoble & Caplan, 1977; Flanagan & Webb, 1964). These effects are analogous to the nonassociative phenomena of external inhibition and disinhibition in classical conditioning. Pavlov (1927) first reported that a conditional response (CR) could be diminished in magnitude by presenting a novel stimulus simultaneously with the conditional stimulus. This effect was termed external inhibition. External disinhibition occurs when an inhibited CR (which has been reduced in magnitude and/or probability by an inhibitory operation such as extinction) is at least partially restored by presentation of an extraneous stimulus. Pavlov considered external disinhibition to represent the unconditional inhibitory effect of the external stimulus on already-existing internal inhibition.

There is a striking similarity between the procedures that lead to external disinhibition of operant behavior and conditional acceleration of operant behavior. Both involve independent presentation of an extraneous stimulus while an animal is engaged in operant responding. Both are most likely if the operant rate has been lowered by an inhibitory procedure such as extinction or DRL. Although the notion of inhibition can be problematic (see Discussion), we proposed that acceleration of DRL responding under superimposed classical-conditioning procedures represents disinhibitory control by the CS. This possibility

was investigated by exposing animals to independent presentations of neutral and reinforcing stimuli as they responded under a DRL schedule. The effects of these extraneous stimuli on operant and collateral responding were compared with those of a prefood stimulus.

METHOD

Subjects

Three experimentally naive male hooded rats were food deprived for 23 hr prior to each daily session. Water was freely available at all times. The subjects were approximately four months old when the experiment began.

Apparatus

A standard single-lever conditioning chamber (Lafayette Instruments) measuring 23 cm by 23 cm by 24 cm high was modified for this experiment. The lever was centered on the intelligence panel, 10.5 cm above the wire-mesh floor. A bidirectional running wheel (Wahman Manufacturing) was mounted outside the chamber, accessible through a door centered in the wall to the left of the intelligence panel. The wheel was modified so that any 60° rotation was automatically recorded. A water tube and a wooden tongue depressor (a flat piece of wood, 2 cm by 15 cm by 1.2 mm) were mounted on the wall to the right of the intelligence panel. The tongue depressor was attached to a microswitch outside the chamber and protruded 8.7 cm into the chamber, 20 cm above the floor. The height of the tongue depressor required the rat to stand on its hind legs to make contact. This insured that the rat would exert sufficient force against the tongue depressor to activate the microswitch to which it was attached. A new tongue depressor was placed in the chamber for each session. In the final phase of the experiment, when one rat (Rat 3) greatly increased its rate of chewing, three tongue depressors were joined together for triple thickness and mounted as described above. Contact with the drinking tube, located 10 cm directly below the tongue depressor, was detected by a drinkometer (Grason-Stadler). Reinforcers (45-mg Noyes food pellets) were delivered to a food cup on the intelligence panel, 4.5 cm to the right of center, and 7 cm above the floor. Two stimulus lamps were located on the intelligence panel, 16 cm above the floor—one above

the food cup and one above the lever. An empty solenoid-operated liquid dispenser, located behind the intelligence panel, 8 cm left of center, was used to produce auditory stimuli. The conditioning chamber was housed in a refrigerator shell. Sound masking was provided by a ventilating fan in the shell and by white noise in the experimental room. Electromechanical control equipment was in an adjoining room. Lever presses and reinforcements registered on digital counters; all stimulus and response events also registered on an event recorder running at 1 mm/sec.

Procedure

Rats were trained to lever press and exposed to an ascending series of DRL values from 3 to 30 sec, incremented by 3 sec every fifth session. Fifty reinforcers were delivered per session under DRL values up to 27 sec. With the introduction of DRL 30-sec, session length was fixed at 60 min for the remainder of the experiment. After 54 daily sessions on DRL 30, Phase I began. Subjects were habituated to the novel compound stimulus that would subsequently serve as the CS. Presentations of the neutral stimulus (NS) were superimposed on the DRL 30-sec baseline. The compound stimulus, initially lasting 10 sec, consisted of 10-Hz solenoid clicks and flashing red and green panel lights. An average of three stimulus presentations per session was arranged by a variable-time (VT) 10-min tape programmer (interval range 24 to 2700 sec) in series with a probability gate set to .50. The effect of the stimulus on lever pressing was measured by an inflection ratio, defined as the number of responses during the stimulus divided by that number plus the number of responses during an equal period immediately preceding the stimulus. Ratios above .50 indicate acceleration of lever pressing and ratios below .50 indicate suppression. Because all rats showed acceleration that did not fully habituate during 32 daily sessions, stimulus duration was increased to 20 sec, and habituation (inflection ratio about .50) occurred within 5 to 11 sessions.

During the next, classical-conditioning phase of the study (Phase II), all stimulus (CS) presentations terminated after 20 sec with delivery of a pellet (the unconditional stimulus or US). In addition, an approximately equal number of pellets was presented indepen-

dently of stimuli or responses (unsignaled food). The VT 10-min tape programmer scheduled both CS and unsignaled-food presentations. Output from the tape programmer sampled a probability gate set at .5 that determined whether a CS or unsignaled-food presentation would occur. Each event occurred on the average of three times per 60 min session. Phase II lasted for 28 daily sessions.

In Phase III no extraneous stimuli were presented, but the DRL 30-sec schedule remained in effect. After 10 days, access to the running wheel was prevented for 10 additional days, to assess the contribution of collateral running to DRL performance.

RESULTS

Conditional Acceleration

During the classical-conditioning phase (Phase II), all three rats showed higher rates of responding during the CS than during the pre-CS period. This accelerative effect is shown in Figure 1, which depicts mean inflection ratios in two-session blocks. Although acceleration developed at different rates across the three animals, all showed reliable acceleration after six sessions (approximately 18 CS-US pairings). Absolute rates of responding during the CS and during the 20-sec pre-CS period are also shown in Figure 1. There was little change in rate of responding during the pre-CS period over sessions, suggesting that the classical-conditioning procedure produced no general disruption of DRL performance. Since unsignaled food could not occur during the pre-CS period, these data do not reflect local effects of this event.

Further evidence of the stability of baseline DRL performance appears in Figure 2, which shows reinforcers earned per session in two-session blocks. The dashed horizontal line indicates mean reinforcers per session during the last five habituation sessions. The classical-conditioning procedure resulted in little loss of reinforcement for Rats 2 and 3 but a small, temporary disruption of DRL efficiency for Rat 1.

Collateral Activity

Analysis of recorded collateral activity showed that for all rats, wheel running occurred most often, followed by drinking. Wood chewing was rare. Figure 3 shows cu-

Fig. 1. Inflection ratios for the CS during the classical-conditioning phase. Values above the dashed horizontal line indicate acceleration. Also shown are mean rates of responding during the CS (DURING CS) and during the 20-sec period immediately preceding CS onset (PRE-CS). All data points represent two-session means.

mulative duration per session of each collateral activity, averaged over the last five sessions of each phase. Rat 3 showed an increase in duration of wood chewing when running was prevented (Phase III), whereas Rat 1 and Rat 2 showed no change. Drinking changed very little as a result of this manipulation.

Figure 4 shows the effects on DRL performance of preventing the high-frequency collateral response of wheel running in Phase III. Rat 1 showed an increase in rate of responding when running was prevented, Rat 3 showed a decrease, and Rat 2, which previously had a very low rate of running, showed little change in rate of lever pressing. Efficiency of DRL performance was assessed in terms of the number of reinforcers earned per session relative to the number that would have been earned had the animal spaced its lever presses perfectly. This index is sensitive to interresponse times that are either too short or unnecessarily long. Rat 1 showed a large decrease in DRL efficiency, suggesting that running had been functional in maintaining DRL performance.

Fig. 2. Number of reinforcers earned per session during the classical-conditioning phase, plotted in two-session blocks. The dashed horizontal line indicates mean reinforcers per session during the last five sessions of the habituation phase.

Rat 2 showed little change, and Rat 3 showed a marked increase.

Sequential Patterns of Behavior

Regardless of their rates for individual rats, all collateral activities were strongly disrupted by CS onset. This conclusion is based on sequential analysis of all recorded activities in the presence and in the absence of the signal. Six exhaustive behavioral categories were established for this analysis. The three recorded collateral activities—running, drinking,

EXPERIMENTAL PHASE

Fig. 3. Mean cumulative duration of each collateral activity during the last five sessions of each phase.

Fig. 4. Rate of lever pressing and DRL efficiency preceding (left of dashed, vertical line) and following prevention of wheel running.

and chewing—formed the categories, RUN, DRINK, and CHEW. The response unit for these categories was the bout, defined as all consecutive instances of an activity separated by interresponse times of less than 2 sec. Lever pressing was divided into two categories. Non-criterion lever presses (those which did not meet the DRL requirement) formed the category LP:NRF. Criterion lever presses formed the category LP:RF. For some analyses these categories were combined into a single category: LP. The sixth category—OTHER—was composed of periods >6 sec during which no recorded activity occurred. This category was included because recorded activities occupied less than half of each animal's session time. Therefore, a sequential analysis based only on recorded activities would present a distorted picture of the animals' behavior. For example, without OTHER, two recorded activities (say, RUN and LP) separated by a long interval of unrecorded activity would be considered to be sequential (RUN → LP). In the present analysis this sequence would be designated RUN → OTHER → LP.

Table 1 shows first-order conditional probabilities for response sequences occurring in the absence of the signal. The conditional probability for any two-response sequence was computed by dividing the frequency of that sequence by the frequency of all sequences initiated by the same activity. From the table, one can read the baseline probability with which a given activity ("Initial Activity") was followed by any one of the six behavioral categories ("Next Activity"). For example, for Rat 1 the probability with which a nonreinforced lever press was followed within 6 sec by another nonreinforced lever press was .44 ($p\{LP:NRF|LP:NRF\} = .44$). The values presented in Tables 1 and 2 are means based on the last seven sessions of the classical-conditioning phase. Total instances of each initial activity during the seven sessions are indicated parenthetically. The conditional probabilities in Table 1 constitute a baseline against which to compare the effects of the superimposed stimuli.

Table 2 describes the behavior sequences formed by (a) the last activity prior to CS onset and (b) the first activity following CS onset. For example, given that Rat 3 emitted a non-reinforced lever press immediately prior to CS onset, the probability that the first activity af-

Table 1
Conditional Probabilities for Baseline Activity Sequences

Rat Number	Initial Activity	Next Activity					
		LP:NRF	LP:RF	Run	Drink	Chew	Other
1	LP:NRF (1112)	.44	—	.13	.01	.00	.42
	LP:RF (326)	.24	—	.10	.06	.01	.59
	RUN (901)	.14	.10	.37	.00	.00	.39
	DRINK (65)	.19	.30	.00	.31	.00	.20
	CHEW (20)	.27	.00	.00	.14	.26	.33
	OTHER (975)	.37	.23	.39	.00	.01	—
2	LP:NRF (1306)	.24	—	.12	.03	.00	.61
	LP:RF (155)	.11	—	.01	.00	.00	.88
	RUN (345)	.39	.07	.25	.07	.00	.22
	DRINK (158)	.61	.02	.01	.04	.02	.30
	CHEW (20)	.71	.00	.00	.00	.00	.29
	OTHER (1055)	.61	.13	.15	.09	.02	—
3	LP:NRF (1349)	.28	—	.25	.05	.00	.42
	LP:RF (164)	.14	—	.09	.20	.00	.57
	RUN (920)	.35	.07	.16	.19	.00	.23
	DRINK (288)	.49	.11	.12	.04	.01	.23
	CHEW (36)	.64	.00	.00	.00	.11	.25
	OTHER (877)	.44	.08	.43	.04	.01	—

ter CS onset was running equaled .20 ($p\{\text{RUN}|\text{LP:NRF}\} = .20$). Comparison of Tables 1 and 2 indicates that CS onset greatly disrupted each animal's pattern of responding. In the absence of the CS, the recorded collateral activities were followed by a lever press approximately half the time (Table 1). However, if a CS occurred during or within 6 sec of any collateral activity, collateral activity was aban-

doned in favor of a lever press in 25 of 26 cases (Table 2). Similarly, CS onset greatly elevated the probability with which behavior in the other categories was followed by a lever press. In fact, CS onset was nearly always followed by a lever press, regardless of what the animal had previously been doing.

Elevation in the probability of lever pressing by CS onset can also be seen in Figure 5.

Table 2
Conditional Probabilities for Response Sequences Formed
by the Activities Prior to and Following CS Onset

Rat Number	Activity Prior to CS	Activity Following CS					
		LP:NRF	LP:RF	Run	Drink	Chew	Other
1	LP:NRF (5)	1.00	—	.00	.00	.00	.00
	LP:RF (0)	—	—	—	—	—	—
	RUN (9)	.89	.11	.00	.00	.00	.00
	DRINK (0)	—	—	—	—	—	—
	CHEW (0)	—	—	—	—	—	—
	OTHER (5)	.60	.20	.00	.00	.00	.20
2	LP:NRF (4)	1.00	—	.00	.00	.00	.00
	LP:RF (0)	—	—	—	—	—	—
	RUN (4)	.75	.00	.25	.00	.00	.00
	DRINK (0)	—	—	—	—	—	—
	CHEW (0)	—	—	—	—	—	—
	OTHER (10)	.90	.00	.00	.00	.00	.10
3	LP:NRF (5)	.80	—	.20	.00	.00	.00
	LP:RF (0)	—	—	—	—	—	—
	RUN (11)	1.00	.00	.00	.00	.00	.00
	DRINK (2)	1.00	.00	.00	.00	.00	.00
	CHEW (0)	—	—	—	—	—	—
	OTHER (5)	.60	.00	.20	.20	.00	.00

Fig. 5. The conditional probability of a lever press given several antecedent conditions. Data were obtained from the last seven sessions of the classical-conditioning phase.

Here the overall probability of lever pressing, $p(LP)$, is plotted as a function of several antecedent events. During the last seven days of classical conditioning, average $p(LP)$ following CS onset ranged from .82 to .96 across the three rats (rightmost set of bars). For comparison, the leftmost set of bars represents the average probability of lever pressing in all consecutive 6-sec intervals during each session (excluding CS periods). This baseline measure, $p(LP|6 \text{ sec})$, ranged between .22 and .27 for the three rats. Pairwise t tests were conducted to determine if $p(LP|6 \text{ sec})$ differed from the probability of lever pressing following other events. The resulting t ratios are presented for each rat in the top panel of Table 3. As can be seen in the last column, $p(LP|CS)$ was significantly elevated over the baseline measure for each rat.

External Disinhibition

Evidence for external disinhibition was also found. As shown in Figure 5, presentation of unsigaled food resulted in a local increase

Table 3
 t Ratios Comparing $p(LP)$ Following Several Antecedent Events $\pm$

		S^R	US	Un- sigaled Food	CS
<i>RAT</i>					
6 sec	1	1.62	2.27	5.42**	20.10***
	2	8.87***	1.16	6.84***	9.09***
	3	5.72**	0.14	5.16*	6.23***
S^R	1		1.78	4.48*	
	2		3.25	9.55***	
	3		1.61	6.30***	
US	1			1.17	
	2			4.67*	
	3			3.98*	
α for each comparison		Overall α			
•		.008			
••		.002			
•••		.001			
$\pm df = 6$					

in the probability of lever pressing over baseline. Table 3 shows that this effect was reliable. Figure 5 also shows that food presentation following the CS (food US) or following a lever press (food S^R) did not reliably increase $p(LP)$. For example $p(LP|US)$ was not significantly different from baseline, whereas food presentation following criterion lever presses (reinforcement) lowered $p(LP)$ below baseline levels for Rats 2 and 3. This last observation follows of course from the temporal contingencies of the DRL schedule, under which $p(S^R)$ is lowest immediately following S^R . The disinhibitory effect of unsigaled food is summarized under the column labeled unsigaled food in Table 3. The t ratios presented in the table show that in the majority of cases, the probability of a lever press following unsigaled food was significantly greater than that following the other types of food presentation.

Evidence for external disinhibition also occurred during the habituation phase, where the 10-sec click/flash neutral stimulus accelerated lever pressing. This can be seen in Figure 6, which presents inflection ratios for all habituation sessions. The breaks in each function separate sessions in which the neutral stimulus was 10 sec long from those in which it was 20 sec. Inflection ratios were based on the number of responses during the stimulus

Fig. 6. Inflection ratios for the 10-sec NS and the 20-sec NS. The breaks in each function indicate transition from 10- to 20-sec stimulus durations (see arrows). Also shown are inflection ratios for 10- or 20-sec control periods (see text for explanation). Data are plotted in five-stimulus blocks.

compared with the number of responses during an equal time preceding the NS. Also shown are inflection ratios computed for three randomly chosen 10-sec or 20-sec control periods in each session. Because rates of responding during the control intervals were often zero, inflection ratios were computed across five-stimulus blocks. For this reason, and because the number of stimulus presentations within sessions varied, the X-axis in Figure 6 represents consecutive blocks of stimulus presentations, rather than sessions. All three animals showed acceleration of lever pressing during the 10-sec NS, although this effect waxed and waned for Rat 2. Inflection ratios for the 20-sec NS were not different from control ratios.

DISCUSSION

All three rats showed marked acceleration of lever pressing during a 20-sec prefood stimulus. The magnitude of this effect is somewhat surprising since, at best, a weak contingency was arranged between the CS and food presen-

tation (the majority of food presentations occurred in the absence of the CS). The results are also surprising in the context of other studies showing acceleration during prefood stimuli. In these studies the effect appeared to depend upon a low-rate baseline and a relatively long CS-US interval. Although the present study used a low-rate baseline, the CS was much shorter than that employed by other investigators who have demonstrated acceleration. Meltzer and Brahlek (1970) found acceleration of lever pressing maintained by a VI 2-min schedule when the prefood stimulus was 120 sec but suppression when the stimulus was 12 or 40 sec long. Henton and Brady (1970) found no effect of 20- and 40-sec prefood stimuli on the DRL 30-sec performance of monkeys but acceleration during an 80-sec stimulus. Kelly (1973) also found acceleration of DRL performance in monkeys during a long (60-sec) CS. In a review, Blackman (1977) concluded that rats' and monkeys' behavior is consistently suppressed during short prefood stimuli. The results presented here and elsewhere (Meltzer & Hamm, 1974b) indicate that this generalization is premature.

Because conditional acceleration is an unusual response to both prefood and preaversive stimuli, Blackman (1968) suggested that it may be related to properties of the DRL schedules under which it is frequently observed. The present study tested Blackman's proposal that acceleration of DRL responding is due to suppression of collateral behavior. To the extent that collateral behavior functions to maintain spaced responding, its disruption should lead to an increase in rate of lever pressing. Blackman's rats did engage in stereotyped collateral activities, and these activities disappeared during the CS. Our rats also engaged in collateral behavior that was consistently abandoned in favor of lever pressing at CS onset. However, two observations suggest that disruption of collateral behavior cannot adequately account for the acceleration of lever pressing observed in our study. First, disrupting the high-frequency response of running by preventing access to the wheel did not result in acceleration of lever pressing in two of three animals (Figure 4). In fact, Rat 3, which had a high rate of running, showed a marked decrease in rate of lever pressing when running was prevented. Second, acceleration of lever pressing was not restricted

to instances in which recorded collateral behavior was disrupted. Table 2 shows that the conditional probability of lever pressing was greatly increased by CS onset regardless of what the animal had been doing at the time, even if it was lever pressing. In almost every case the animal quickly abandoned its previous activity and initiated a lever press (mean latency to lever press following CS = 3.8 sec). Although the grain of our analysis (6 sec) does not preclude the possibility that CS onset reliably disrupted some short-duration unrecorded collateral behavior, we conclude that in this study acceleration of lever pressing did not depend on disruption of collateral behavior.

An alternative explanation for the acceleration of lever pressing during the CS is based on the nonassociative phenomenon of external disinhibition. Operant responding that has been reduced in rate by some inhibitory operation can generally be increased (disinhibited) by a variety of extraneous stimuli (Brimer, 1972). All three of our animals showed disinhibition of spaced lever pressing following onset of a neutral or a reinforcing extraneous stimulus. Throughout most of the 32 habituation sessions, all rats showed marked acceleration of lever pressing during 10-sec presentations of the neutral stimulus which was to become the CS. During the classical-conditioning phase, independent presentations of food (unsigaled food) greatly elevated the probability of lever pressing. These findings, which are similar to those of Contrucci, Hothersall, and Wickens (1971) and DeNoble and Caplan (1977), indicate that the DRL 30-sec baseline was susceptible for many sessions to disruption by extraneous stimuli.

Although disinhibition-like phenomena have been widely reported (e.g., Brimer, 1972), their interpretation raises some problems. The first concerns the status of inhibition as an explanatory construct. Skinner (1938) and subsequent writers have argued on both logical and empirical grounds that inhibition is, at best, an unparsimonious way to describe a decrease in response rate. On the other hand, writers influenced by Pavlov (1927), Hull (1943), and Spence (1956) have argued that (1) inhibitory control can be measured (Hearst, Besley, & Farthing, 1970), and (2) inhibition is a necessary construct in understanding acquisition of stimulus control (Rescorla & Wagner, 1972).

The wealth of research based on these seminal papers testifies to the heuristic value of the construct.

The second problem presented by the concept of inhibition is more directly related to the argument raised in the present report. We have proposed that acceleration of lever pressing during the CS resulted from a release from inhibition (i.e., external disinhibition) produced by the DRL baseline schedule. Unfortunately we have no independent assessment of the presumed inhibition. As Skinner as well as Hearst et al., have pointed out, a low rate of responding is insufficient basis for inferring inhibitory control. Nevertheless, many authors have argued that behavior maintained by DRL schedules is best understood in terms of inhibition (Brimer, 1972; Contrucci, Hothersall, & Wickens, 1971; Halliday & Boakes, 1972; Richelle, 1972; Terrace, 1972). Furthermore, Gray (1976) has provided some direct evidence that a DRL schedule can produce inhibitory stimulus control. We would therefore argue that there are sufficient grounds for regarding the DRL schedule as a source of inhibitory control.

Analysis of acceleration during the CS in terms of external disinhibition implies that this effect is nonassociative, i.e., independent of pairings between the CS and US. Such an analysis seems particularly reasonable for the present study in which the CS-US contingency was severely degraded by presentations of the food US in the absence of the CS (Gibbon, Berryman, & Thompson, 1974; Rescorla, 1968). However it might also be argued that the acceleration produced by the CS during the classical-conditioning phase is at least partially attributable to associative processes. This follows from the observation that, once the behavioral effect of the "neutral" click/flash stimulus habituated, acceleration to this stimulus re-emerged gradually across many CS-US pairings. Because stimulus- and response-independent food presentations did not occur during baseline, we cannot determine whether this change in status of the CS resulted from CS-US pairings, or simply from introduction of response-independent food. However, Hoffman, Fleshler, and Jensen (1963) showed that the effects of a stimulus on operant behavior can be altered by a nonassociative procedure. Conditional suppression was established in pigeons responding on a VI 2-min schedule for

food by pairing an auditory CS with shock. Then auditory generalization gradients were obtained in sessions without shocks. Thirty months later, after spontaneous recovery of suppression was extinguished during further generalization testing, the original generalization gradients were quickly restored by presentation of unsignaled shocks. The authors attributed their findings to emotional stress caused by the unsignaled shocks, but an alternate suggestion is that the shocks restored the salience of the CS and similar stimuli (a phenomenon like sensitization). Similarly, it can be argued that introduction of response-independent food in the present study restored the salience of the habituated click/flash stimulus, thereby rendering it once again an effective disinhibitor.

An alternative interpretation of the effects of CS-US pairings in the present study is provided by a response-competition hypothesis (Brady & Hunt, 1955; Henton & Brady, 1970; Henton & Iversen, 1978). According to this associative analysis, the effects of concurrent classical and instrumental conditioning depend upon the topography of responding controlled by the CS. If CS-associated behavior is incompatible with the operant, conditional suppression will occur; if compatible, conditional acceleration. This theory can account for the effects of several parameters, including quality and magnitude of the US (Azrin & Hake, 1969; Mandell, Note 1), location and modality of the CS (Karpicke, 1978; Karpicke, Christoph, Peterson, & Hearst, 1977; Schwartz, 1976), and topography of the operant response (LoLordo, McMillan, & Riley, 1974). The present theory is silent regarding these parameters. However, it should be noted that the response-competition hypothesis and the present account are not mutually exclusive. A reasonable assumption is that both associative and nonassociative factors can be active in concurrent instrumental and classical conditioning.

In addition to the present data, external inhibition and disinhibition can help explain other results that have previously been difficult to interpret. Kelly (1973) showed conditional acceleration in rhesus monkeys during a prefood stimulus when the operant baseline was a DRL schedule and conditional suppression when the baseline was an RR schedule. Similarly, Blackman (1968) reported acceleration of DRL responding in rats during a CS

that preceded mild shock and suppression of fixed-interval, limited-hold (FI LH) behavior during the same stimulus. As Kelly has noted, theories that account for conditional suppression in terms of competing responses or emotional states elicited by the CS cannot also account for conditional acceleration by the same CS when it is presented on a different operant baseline. On the other hand, Kelly's and Blackman's data are readily interpreted as examples of external inhibition and disinhibition. As Brimer (1972) has pointed out, an extraneous stimulus will normally have an inhibitory effect when presented on a baseline of reinforced responding, but if the baseline is inhibitory, an extraneous stimulus will then have a disinhibitory effect. The DRL baselines used by Kelly and Blackman can be presumed inhibitory, whereas the RR (Kelly) and FI LH (Blackman) schedules cannot. Therefore, an extraneous stimulus (in this case, the CS) would be expected to accelerate behavior maintained by the DRL schedules, while suppressing behavior maintained by the RR or FI LH schedules. Although there are exceptions (e.g., Blackman & Scruton, 1973; Meltzer & Hamm, 1974a; Osborne & Killeen, 1977; Randich, Jacobs, LoLordo, & Sutterer, 1978; Smith, 1974), much of the literature on the effects of classical conditioning on operant behavior is consistent with our argument. Acceleration during a CS is most reliably obtained when the operant baseline can be described as inhibitory (Baum & Gleitman, 1967; Blackman, 1968; Bolles & Grossen, 1970; Estes, 1948; Henton & Brady, 1970; Kelly, 1973; Meltzer & Hamm, 1974b), whereas suppression usually occurs in all other cases (for a review see Blackman, 1977).

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