INCENTIVE PROCESSES AND THE PEAK SHIFT

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Intradimensional operant discrimination schedules were employed, which eliminated the covariation of response and reinforcement rates that are found on most operant baselines. In Phase 1, one keylight (S_1) controlled an increase in pigeons' treadle pressing, relative to another keylight (S_2), while being correlated with a decrease in frequency of reinforcement. In Phase 2 both treadle pressing and reinforcement increased in the presence of one keylight, relative to the second. In Phase 1 the relatively flat treadle-press generalization gradients peaked at S_1 , whereas the peaks of those in Phase 2 were shifted from S_1 in a direction away from S_2 . It was postulated that these positive and negative stimulus-reinforcement contingencies influence the likelihood of obtaining peak shift through the operation of a classically conditioned "central motive state." How response-reinforcement and stimulus-reinforcement contingencies might contribute to the development of inhibitory effects of S_2 is discussed. Autoshaped key pecking also was produced by these procedures. During manipulations of stimuli, the gradients obtained for autoshaped key pecking were narrow and sharply peaked at the food-correlated stimulus (S_2) in Phase 1. This failure to obtain peak shift for an elicited response suggests a difference in discriminative processes operating in classical and instrumental learning.

Key words: intradimensional discrimination training, peak shift, incentive, stimulus control, two-process theory, autoshaping, treadle pressing, pigeons

It has long been appreciated that within instrumental learning situations, response-reinforcer ($R-S^R$) and stimulus-reinforcer ($S-S^R$) contingencies can be distinguished (Mowrer, 1947; Schlosberg, 1937). As a discriminative stimulus (S^D) gains control of a change in behavior through the $R-S^R$ contingency operating, the same stimulus customarily becomes differentially associated with reinforcement—creating an $S-S^R$ contingency. According to two-process learning theorists, these $S-S^R$ associations influence or "mediate" the rate of instrumental response emission through an incentive-motivational mechanism (Rescorla & Solomon, 1967; Weiss, 1978). Since this motivational mechanism can influence a variety of arbitrarily chosen operants, and peripheral correlates of its operation are often difficult to

identify or measure (Rescorla & Solomon, 1967, pp. 164-170), it is postulated to be "central" in nature. This position should be distinguished from those two-factor applications that focus on peripheral responses elicited by $S-S^R$ contingencies. For example, the additivity theory of behavioral contrast suggested by Schwartz and Gamzu (1977) deals exclusively with the direct summation of operant and elicited key pecks.

Unfortunately, since response and reinforcement rates covary on most operant baselines, until recently only indirect support was available for the position that operants were mediated by an incentive-motivational mechanism established in the instrumental situation. Such indirect support has been supplied by transfer-of-control experiments where Pavlovian conditioned stimuli established off the operant baseline are subsequently presented while the subject is engaged in an independently acquired operant performance (Overmier, 1978). However, through the appropriate choice of multicomponent operant baselines, the discriminative control of the operant and the implicit differential Pavlovian conditioning established between components can be independently manipulated exclusively within the

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instrumental situation. This has been accomplished under conditions of positive reinforcement (Weiss, 1969, 1971, 1977; Weiss & Van Ost, 1974) and of negative reinforcement (Emurian & Weiss, 1972; Weiss, 1976, 1977). For example, in the case of positive reinforcement, rats were trained to respond in the presence of tone and of light and to cease responding when these stimuli were both absent ($\overline{T+L}$). What distinguished the various groups of rats was the frequencies of reinforcement accompanying tone and light relative to the frequencies accompanying $\overline{T+L}$. In tone and in light, reinforcement rates were higher, remained unchanged, or were lower than $\overline{T+L}$, depending upon the group. This training was followed by stimulus compounding tests where the tone-plus-light compound was presented for the first time. In these tests the compound produced a) three times the single-stimulus response rate when tone and light each controlled a higher response rate and signaled a higher rate of reinforcement; b) two times the single-stimulus response rate when tone and light each controlled a higher response rate but signaled no change in rate of reinforcement; and c) the same response rate as for the single stimuli when tone and light each controlled a higher response rate and signaled a lower rate of reinforcement. When response and reinforcement rates were both elevated in the presence of tone and in light, maximum additive summation was obtained. When only response rate was elevated in the presence of these stimuli, moderate additive summation was produced in compounding. Finally, when the single stimuli had accompanied an increase in response rate, while being correlated with a decrease in rate of reinforcement, these two variables appeared to neutralize each other—with no summation observed in testing. An algebraic combination rule applied to these variables describes this pattern of results (Weiss, 1978).

Through logical extension, Weiss (1978, pp. 370-372) postulated that manipulation of relative response and reinforcement rates during intradimensional discrimination training might affect the likelihood of peak shift during subsequent generalization tests in much the same way that these variables affect the results of stimulus compounding. The influence of incentive states produced by stimulus-reinforcer relations has been discussed by numerous the-

orists as affecting ongoing instrumental behavior. However, Weiss was the first to systematically address the operation of this mechanism in the production of peak shifts in stimulus generalization gradients. In these peak shifts, maximal response rates are controlled by stimuli removed from those of highest rates during training (S_1) in a direction away from those controlling the lowest rates (S_2) (Hanson, 1959). According to Weiss' formulation, the likelihood of peak shift is maximized when S_1 is correlated with both an increase in response and reinforcement rate relative to S_2 , training conditions characterizing the vast majority of the studies in this area. On the other hand, Weiss' combinational model predicts a minimal likelihood of peak shift when S_1 is discriminative for an increase in response rate, but signals a decrease in rate of reinforcement.

Only one generalization study has established these conflicting response and reinforcement relationships to S_1 , and it supported Weiss' combinational assumptions. Yarczower, Gollub, and Dickson (1968) maintained key pecking in the presence of a keylight with a wavelength of 550 nm using a variable-interval (VI) schedule of food reinforcement. In the presence of a 570 nm light, a differential-reinforcement-of-other-behavior (DRO) schedule was in effect such that the cessation of key pecking produced triple the reinforcement frequency correlated with the 550 nm light. In a subsequent stimulus-generalization test, only one of four birds showed peak shift.

In light of the importance of this outcome for supporting the application of two-process principles to an analysis of peak shift, Yarczower et al.'s (1968) findings should be replicated. This is especially important because we now know that key pecking is influenced both by operant and by respondent contingencies. Yarczower et al.'s results could be interpreted in terms of conflicting peripheral operants and respondents (Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977).

Several investigators have reported that if, for pigeons, one keylight accompanies a schedule of response-independent reinforcement that is denser than the schedule accompanying a second keylight with which it alternates, autoshaped key pecks would be elicited more frequently by the stimulus correlated with the higher density of reinforcement (Gamzu &

Schwartz, 1973; Hamilton & Silberberg, 1978). This means that if the instrumental contingencies were not operating in the Yarczower et al. (1968) study, and the three-to-one reinforcement density difference between 570 and 550 nm keylights was established through a random-time schedule independently of the pigeons' behavior, key pecks would have been elicited by the stimulus accompanied by the higher reinforcement density. However, this was the stimulus (570 nm) in the presence of which reinforcement was contingent upon cessation of key pecking. Thus, there probably existed a conflict between operant and respondent control of the key-peck response. A complementary conflict would be expected in their VI schedule component (550 nm) where key pecking was necessary for reinforcement but where reinforcement density was one-third of that in the DRO component. It could be argued that this peripheral response conflict was responsible for Yarczower et al.'s failure to obtain peak shift.

The study reported below further examined the characteristics of stimulus control when a stimulus controlled an increase in rate of responding while signaling a decrease in frequency of reinforcement. The procedure was designed to minimize interference between operants and respondents at the peripheral level. Pigeons were again employed as subjects, but treadle pressing was the operant in the present experiment. This operant is arbitrary with respect to the consummatory response produced by food in the pigeon and seems unrelated to elicited key pecking even when both are measured in the same situation (Bushnell & Weiss, 1980, Experiment 1B). Thus in the present situation, unlike those where key pecking is the operant, the main dependent variable should be relatively unaffected by auto-shaped peripheral respondents.

Bushnell and Weiss (1980) have already demonstrated peak shift in each of six pigeons whose treadle-press responding was reinforced with food on a multiple VI extinction (EXT) schedule where S_1 was correlated with an increase in both response rate and reinforcement frequency. Phase 1 of the present experiment arranged for S_1 to be correlated with an increase in response rate and a decrease in rate of reinforcement, relative to S_2 —conditions minimizing the likelihood of peak shift according to Weiss (1978). In an attempt at

systematic replication, in Phase 2 the birds were placed on the multiple VI EXT schedule previously employed by Bushnell and Weiss. Here, differential rates of treadle-press responding would be maintained as in Phase 1, but the likelihood of peak shift should be enhanced since S_1 is correlated with an increase in both response and reinforcement rate. Key pecking elicited by the keylights was monitored during training and generalization testing in both phases of the experiment.

METHOD

Subjects

Three Silver-King pigeons, approximately one year old at the beginning of the experiment, served. They were maintained at 80% of their free-feeding weights. All were experimentally naive and were housed separately with free access to water and grit.

Apparatus

An operant conditioning chamber measuring 32.5 cm high by 29.5 cm long by 23 cm wide was used. The chamber was a stainless steel box containing a foot treadle 5 cm long by 5 cm wide. The treadle, located on the front wall, was 4 cm from the left wall, 14 cm from the right wall, and 3 cm from the floor. A force of .6 N at the center of the treadle and a downward displacement of 1 cm were required to operate a microswitch connected to the treadle. Centered 18 cm above the treadle was a stimulus key 2 cm in diameter. The stimulus key was operated by a force of .15 N. A food magazine 6 cm wide and 6 cm high was located 13 cm from the left wall, 4 cm from the right wall, and 4 cm from the floor. The chamber was enclosed in a sound-attenuating chest with an exhaust fan mounted in the ceiling. This fan also served to mask extraneous noise. Electromechanical equipment, located in an adjacent room, arranged the schedule contingencies and stimulus presentations. Data were recorded on digital counters and were also monitored on a cumulative recorder.

The visual stimuli projected on the stimulus key were generated by Dectric Optics two-cavity interference filters with 5-nm bandpass and both ultraviolet and infrared blocking. Peak transmissions of the filters were at 540, 552, 558, 567, 572, 575, 580, 588, 598, and 611 nm. The illumination source was a GE 18-amp

T10/2p6v microscope illuminator bulb with ribbon filament and an output of 1800 lumens. The spectral emission between 540 and 610 nm was best fit by a black body radiator with a color temperature of 2850 degrees K. The spectral energy distribution in this wavelength interval has a radiometric range of .2 log units (Wysecki & Stiles, 1967, p. 20). The collimated monochromatic light transilluminated the translucent stimulus key. The lamp source was 50 cm from the key. Each of the 10 filters could be placed in the path of the light beam by activating the appropriate solenoid.

Procedure

The pigeons were initially trained to eat grain from the food hopper. The hopper aperture was illuminated and the hopper raised until the pigeon located the grain and ate for 5 sec, after which the hopper was lowered and the light extinguished. During this stage of training, the only source of illumination in the chamber was the aperture light. This magazine training continued until a bird had eaten from the hopper within 2 sec of aperture illumination for five consecutive presentations of the hopper.

Phase 1—Chained VI DRO training. The goal of this training regimen was to establish control on a chain VI DRO schedule wherein treadle pressing in the presence of one keylight (S_1) intermittently produced light of a second wavelength (S_2), where grain reinforcement was contingent upon the cessation of treadle pressing. The use of a chain schedule here insured maximum discriminability in reinforcement differences between schedule components since S_2 accompanied 100% of the grain. Table 1 gives the sequence of training schedules experienced by each subject from initial training through the terminal baselines of Phases 1 and 2. A bird was trained on the terminal training schedule until, for three consecutive days: (1) treadle rate in S_2 (DRO) was no more than 10% of that in S_1 (chain VI), and (2) no increasing or decreasing trend in response rate was evident in either component.

On the day following magazine training, treadle pressing was hand shaped. Shaping was accompanied by S_1 , and any movement that approximated treadle pressing was followed immediately by 3.5 sec of S_2 with hopper illumination and activation. When shaping was completed, treadle presses during S_1 produced

Table 1

Sessions on each successive training schedule in Phases 1 and 2.*

Schedule			Subject		
S_1	S_2		1	2	3
<i>Phase 1</i>					
chained CRF	FT	0	1 (1)	1 (2)	1 (2)
chained FR 2	FT	3	2 (2)		3 (3)
chained FR 4	DRO	5			6 (3)
chained VI 3	DRO	5	4 (4)	3 (2)	
chained VI 3	DRO	10	8 (6)		
chained VI 15	FT	3			9 (2)
chained VI 15	FT	10		5 (5)	11 (2)
chained VI 15	DRO	10	14 (3)		
chained VI 15	DRO	30	17 (14)		
chained VI 30	FT	15			13 (5)
chained VI 60	DRO	40			18 (18)
chained VI 45	DRO	30		10 (4)	
chained VI 45	DRO	45	31 (2)		36 (13)
chained FR 15	DRO	45	33 (19)	14 (9)	
chained FR 15	DRO	20	52 (7)	23 (14)	
chained VI 30	DRO	20	59 (8)		
chained VI 45	DRO	20		37 (3)	
Total Sessions			67	40	49
<i>Phase 2</i>					
mult VI 30	EXT	(60 sec)		1 (2)	
mult VI 60	EXT	(40 sec)			1 (13)
mult VI 45	EXT	(20 sec)		3 (3)	
mult VI 45	EXT	(30 sec)		6 (8)	
mult VI 45	EXT	(45 sec)	1 (25)	14 (25)	14 (8)
Total Sessions			26	39	22

*Subjects experienced only those contingencies for which there are session numbers indicated for them. The numbers not in parentheses indicate the session that contingency was first instituted. The numbers in parentheses specify the total sessions a bird experienced that contingency.

S_2 and grain for 3.5 sec. A 1-sec darkened key accompanied transitions from S_1 to S_2 and from S_2 to S_1 . Training on this chained fixed-ratio (FR) 1 fixed-time (FT) 0-sec schedule continued for one or two sessions wherein the birds earned 75 3.5-sec hopper presentations. For Subjects 1 and 2, the S_1 keylight was 572 nm and S_2 was 580 nm. This correlation was reversed for Subject 3.

Subjects 1 and 3 were next put on a chain FR 2 FT 3-sec schedule wherein 2 responses during S_1 produced S_2 during which grain was presented after 3 sec. Subject 2 was put on a Chain VI 3-sec DRO 5-sec schedule. There the first response emitted in the presence of S_1 after an average of 3 sec had elapsed, produced S_2 . In the presence of S_2 , the bird had to cease treadle pressing for 5 sec for grain to be presented. The schedules were systematically ad-

justed so that after 8 to 18 sessions all birds were working on a chain VI DRO contingency. The DRO was instituted only after treadle rate in S_2 began to show a clear decrease under the fixed-time schedule. To insure that a subject received at least one reinforcement during a DRO component, responses prolonged the component, if necessary, until the DRO requirement was met. When the VI schedule operated during S_1 , this component of the chained schedule was satisfied by the first treadle press emitted after the programmed interval had elapsed. These intervals ranged from 2 sec to three times the mean interval; their scheduling was distributed such that each interval was equally likely to follow any other interval. Sessions lasted until 75 reinforcers were received, which usually required between two and three hours on this and subsequent stages of training.

Whenever a component changed, the key was darkened for .4 sec while the appropriate filter was put in place. To insure that a briefly darkened key did not in itself come to signal a schedule component change, the contingency was modified such that the probability was only .5 that after a blackout a bird would enter a component different than that it had just been in—with the restriction that a component repeat no more than four times. This modification was instituted on Sessions 24, 20, and 19 for Subjects 1, 2, and 3 respectively. This doubled the effective interval of the VI portion of the chain. The resulting reduction in treadle rates during S_1 for Birds 1 and 2 required a return to ratio requirements, for the sessions indicated in Table 1, to bring these rates back to their former levels. Bird 3 remained on Chain VI DRO throughout Phase 1. Prior to testing, as indicated in Table 1, all birds were on a chain VI DRO schedule.

At about the same time as the change to .5 in the probability that a bird would enter a component different than that it had just been in after a blackout, the duration of the DRO components was made independent of the subject's behavior. Now the DRO components were varied within sessions between one-half and twice the DRO value. When one DRO component followed another, the DRO reinforcement clock did not reset between components. By the time a bird was on its terminal training schedule, component change was not predictive of which schedule would be present

or of whether the cessation of treadle pressing during S_2 would always lead to reinforcement. During all phases of training and testing, key pecks were recorded but had no scheduled consequences.

After the discrimination criteria were met (see above) a stimulus generalization test was administered. On the day of the test, the terminal training schedule was in effect for approximately 20 min, after which reinforcement was discontinued and 12 randomized blocks of 10 different key-light stimuli were presented. Each block consisted of a 45-sec presentation of 540, 552, 558, 567, 572, 575, 580, 588, 598, and 611 nm projected on the key. The order of presentation was random within each block, and a .4-sec darkened key separated stimulus presentations. Treadle presses and key pecks were recorded within each test stimulus condition, but neither response produced food during the test.

Phase 2—Multiple VI Extinction Training. Following the stimulus generalization test of Phase 1, the birds were put on a multiple VI 45-sec extinction (EXT) schedule. Here treadle presses during S_1 produced grain on the average of once every 45 sec, the limits of the schedule being two and 135 sec. Treadle pressing in the extinction component had no consequences except to prolong that component such that treadle pressing had to cease for the time defining the minimum duration of the extinction component. This response-reset contingency was instituted after 3, 3, and 9 sessions in Phase 2 for Subjects 1, 2, and 3, respectively. Variable-interval component durations averaged 45 sec, but varied, within sessions, within the limits of 5 and 60 sec. As in Phase 1, there was a .5 probability that a component would be repeated after blackout. A bird's S_1 (chain VI) Phase 1 stimulus was correlated with VI 45-sec grain reinforcement in Phase 2, whereas its S_2 (DRO) Phase 1 stimulus was correlated with extinction in Phase 2. Numbers and sequences of training sessions in Phase 2 and associated schedules are given in Table 1. Training continued on the multiple VI 45-sec EXT terminal Phase 2 contingency until the discrimination criteria of Phase 1 were met. Then a stimulus generalization test like that described for Phase 1 was administered. As in the previous test, no food was presented after the first 20 min of the session.

Table 2

Phase 1 criterion baseline performance for the operant (treadle) and autoshaped (key) responses (responses/min).

Subject		Chain VI DRO			
		Treadle		Key	
		S_1 (VI)	S_2 (DRO)	S_1	S_2
1	$\bar{X}$	17.8	0.4	0.2	29.2
	(SD)	(2.7)	(0.1)	(0.1)	(2.5)
2	$\bar{X}$	20.0	0.5	8.7	136.3
	(SD)	(2.4)	(0.2)	(3.6)	(11.4)
3	$\bar{X}$	6.7	0.4	0.5	17.2
	(SD)	(1.5)	(0.2)	(0.3)	(4.2)
Mean	$\bar{X}$	14.8	0.4	3.1	60.9
	(SD)	(2.2)	(0.2)	(1.3)	(6.0)

RESULTS

Phase 1—Chain VI DRO

Training. Performances from the final four days of training are presented for each bird in Table 2. Clear and stable discriminations were evidenced for both treadle presses and key pecks, with all birds exceeding a 15:1 discrimination ratio on both measures. On average, 97.3% of the treadle presses were emitted during the chain VI component (S_1) of the train-

ing schedule, whereas 95% of the key pecks were elicited during the DRO component (S_2), which included grain delivery.

Testing. The absolute generalization gradients for the treadle press and key peck responses are presented in Figure 1. For each bird maximal treadle pressing accompanied the stimulus value that had controlled the highest rate during training—the value correlated with the VI components of the chain schedule. No bird showed peak shift. All birds reduced, relative to S_1 , their rate of treadle pressing during the stimulus that had been correlated with the DRO contingency in training (S_2). S_2 controlled the lowest treadle-press rate in testing for Bird 1, close to the lowest rate for Bird 3, and an intermediate rate for Bird 2. All birds showed substantially higher rates of treadle pressing in the presence of stimuli removed from the DRO stimulus in a direction away from the chain VI stimulus than in the presence of the low-rate training stimulus itself. Over one quarter of the area under each gradient is contained in the vicinity of those stimulus values beyond S_2 away from S_1 . (These areas will be compared to those contained at comparable stimulus values after the multiple VI EXT training of Phase 2.)

Fig. 1. Wavelength generalization gradients for the operant treadle-press response and for autoshaped key pecks after chain VI DRO training in Phase 1. S_1 was 572 nm for Birds 1 and 2 and 580 nm for Bird 3. Note that the treadle-press rate scale on the left ordinate is approximately one-third that of the key-peck rate scale on the right ordinate.

The key-peck gradient for each bird was sharply peaked at the stimulus correlated with DRO for treadle responding. The gradients for Birds 1 and 2 were symmetrical around this stimulus value and revealed little generalized responding. The gradient for Bird 3 showed some generalization to those stimuli removed from the DRO stimulus in a direction away from the chained VI value. Although stimulus control of treadle pressing appeared to break down during the generalization tests with those stimuli removed from the DRO value in the direction away from the chain VI value, this was not true for the autoshaped key-peck response.

Phase 2—Multiple VI Extinction

Training. Table 3 shows that the quality of the treadle-press discriminative performance in Phase 2 compares favorably with that of Phase 1. On average, 94.5% of the treadle presses were emitted during the VI component of the training schedule. Treadle-press rates in the VI components were comparable between phases for Bird 2, whereas those of Bird 1 decreased over phases, and those of Bird 3 increased. We achieved our goal of producing treadle-press rates in Phase 2 that were not characteristically different from those of Phase 1.

During Phase 2 all reinforcements were received during the VI-correlated stimulus (S_1), whereas the stimulus (S_2) previously associated with the DRO reinforcement contingency now signaled extinction. This caused the rate of key pecking to drop dramatically in S_2 —from 29.2 to .4 pecks per min for Bird 1, from 136.3

to .1 for Bird 2, and from 17.2 to 0 for Bird 3. This dramatic drop in elicited key pecks in S_2 was not matched by a comparable increase in S_1 key-peck rates, which remained essentially similar in Phases 1 and 2. Nevertheless, on average, 94.2% of the key pecks elicited in Phase 2 were elicited in S_1 (the VI food correlated condition).

Testing. The generalization gradients from Phase 2 are presented in Figure 2. On this test all three birds treadle pressed at their highest rates to that stimulus value one step removed from their VI training stimulus (S_1), in the direction away from the stimulus that had accompanied extinction. Thus clear and consistent peak shift was produced, with each of the gradients also declining over those stimulus values beyond that at which they peaked.

The distributions of the areas under the treadle-press gradients produced by each bird during Phases 1 and 2 are presented in Table 4. A significantly larger area of the generalization gradient was contained beyond S_1 in Phase 2 (86.9%) than in Phase 1 (57.2%) ($t_{(2)} = 10.8$, $p < .01$). In addition, for each bird S_2 controlled the lowest, or very close to the lowest, treadle-press rates in testing with less than 8% of the area of any Phase 2 gradient contained in the vicinity of the stimulus values beyond S_2 away from S_1 . This is a significantly smaller area than contained beyond S_2 in Phase 1 ($t_{(2)} = 16.4$, $p < .01$).

The gradients produced by the elicited key pecks during the Phase 2 generalization test do not reveal much consistency. Bird 1 produced an elicited key-peck gradient peaking at the VI-correlated stimulus with some area shift in the direction away from the extinction stimulus. The distribution of Bird 2's key pecks appeared indiscriminate, while practically no key pecks were elicited during the

Table 3

Phase 2 criterion baseline performance for the operant (treadle) and autoshaped (key) responses (responses/min).

Subject		Mult VI Ext			
		Treadle		Key	
		S_2 (VI)	S_1 (EXT)	S_2	S_1
1	$\bar{X}$	12.5	0.7	4.3	0.4
	(SD)	(3.4)	(0.4)	(1.0)	(0.1)
2	$\bar{X}$	21.9	1.8	3.1	0.1
	(SD)	(3.4)	(0.2)	(1.1)	(0.1)
3	$\bar{X}$	21.8	0.7	0.6	0
	(SD)	(2.3)	(0.4)	(0.3)	(0)
Mean	$\bar{X}$	18.7	1.1	2.7	.2
	(SD)	(3.0)	(0.3)	(0.8)	(.1)

Table 4

Distribution of areas under generalization gradients during Phases 1 and 2 (percent of total area).

Subject	Phase 1			Phase 2		
	chain VI DRO			mult VI EXT		
	S_1 away from S_2	S_1 and S_2	S_2 away from S_1	S_1 away from S_2	S_1 and S_2	S_2 away from S_1
1	59.6	11.9	28.5	88.9	8.9	2.2
2	64.3	10.6	25.1	89.5	2.9	7.6
3	47.7	19.2	33.1	82.4	11.0	6.6
$\bar{X}$	57.2	13.9	28.9	86.9	7.6	5.5

Fig. 2. Wavelength generalization gradients for the operant treadle-press response and for autoshaped key pecks after multiple VI 45-sec EXT training in Phase 2, S₁ was 572 nm for Birds 1 and 2 and 520 nm for Bird 3. Note that the treadle-press rate scale on the left ordinate is approximately 1.5 times that of the key-peck rate scale on the right ordinate.

test for Bird 3. These gradients as a whole should be viewed in light of the fact that rates of elicited key pecking in the food-associated component of Phase 2 (VI) were, on average, only 5% of the rates elicited in the DRO component of Phase 1.

DISCUSSION

Operant Treadle Presses

In Phase 1, S₁ was discriminative for an increase in treadle pressing when it was not accompanied by food—conditions appropriate for producing an inhibitor through classical conditioning. In Phase 2, S₁ was again discriminative for an increase in treadle pressing when it simultaneously signaled an increase, to almost 100%, in the probability of receiving food. Thus, between Phases 1 and 2 of this study, the discriminative control of treadle pressing did not systematically change (Tables 2 and 3). Responding was maintained in S₁ and virtually ceased in S₂. Nevertheless, during a stimulus generalization test responding peaked at S₁ for all birds in Phase 1, whereas all birds showed clear peak shift in Phase 2. The impact of the reinforcement manipulation between phases was clear and powerful.

When Yarczower et al. (1968) used key pecking as the operant where a high operant rate was to be maintained by the R-S^R contingency in the low density reinforcement component of a multiple VI DRO schedule, we now realize (see introduction) that conditions were created where operant and elicited key pecks could have been in conflict at the peripheral level. This makes the outcome of that experiment indeterminate regarding predictions of two-process theories contending that Pavlovian processes mediate instrumental responding through a “central” incentive-motivation mechanism (Rescorla & Solomon, 1967; Weiss, 1978). For this reason, treadle pressing was employed as the operant in the present experiment, an operant that seems arbitrary with respect to responses elicited by grain in the pigeon. In the present systematic replication of Yarczower et al., a chain VI DRO was substituted for their multiple VI DRO. Since all grain reinforcement is received in the DRO component of the chain schedule, differential S-S^R associations would be more easily established than on the latter schedule where only a major portion of the grain is received in DRO. On a chained schedule there is a clear preference for components closer to

reinforcement than for those further removed, and this preference can be used as a measure of relative incentive value (Weiss, 1978, pp. 363-364). Thus, in Phase 1 of the present experiment, S_1 (chain VI) controlled an increase in treadle pressing and was correlated with a decrease in incentive motivation.

Other things being equal, a chain VI schedule in S_1 (Phase 1), where reinforcement was delayed, would generate lower rates than would the VI Phase 2 where reinforcement was immediate. If this usual change in rate had been permitted to occur, differences in gradient shape between Phases 1 and 2 could have been attributed to the reinforcement manipulation and/or the consistent difference in S_1 response rates over phases. To contend with this potential problem, S_1 rates of Birds 1 and 2 were enhanced for a period in Phase 1 with a fixed ratio requirement, while Bird 3 remained on chain VI in S_1 throughout Phase 1 after initial training. (All birds were on chain VI DRO prior to testing, however.) As we anticipated, S_1 rates were higher for Bird 3 in Phase 2 than in Phase 1. S_1 rates remained comparable over phases for Bird 2, whereas they decreased between phases for Bird 1. On average, S_1 treadle rates were comparable over phases. Whether treadle rates increased, decreased, or remained unchanged over phases, the generalization gradients for all birds were essentially the same within each phase. This permits us to conclude with confidence that it was the reinforcement (incentive) manipulation that was responsible for the difference in gradient shape between phases, with rate differences having little influence.

Weiss (1978) concluded that when S_1 is correlated with a response and incentive increase relative to S_2 , as it was in Phase 2 of the present experiment, the likelihood of obtaining peak shift is maximized. On the other hand, when S_1 is correlated with conflicting response increase and incentive decrease, as it was in Phase 1 of this study, the likelihood of obtaining peak shift is minimized. The present results support this contention. Further, according to the response/incentive combinational assumption implicit in this formulation, a response rate increase or incentive increase alone in S_1 should be adequate to produce a likelihood of peak shift somewhere intermediate between the extremes defined by the underlying response and incentive processes operating in

concert or in conflict. Although such a group was not contained in the present study, one can be found—with the appropriate control—in an experiment reported by Huff, Sherman, and Cohn (1975). When Huff et al. trained one group of rats on an intradimensional discrimination where S_1 was correlated with an increase in response and reinforcement rates, 100% of their subjects showed peak shift in testing—just as our birds did in Phase 2. In comparison, when S_1 was discriminative only for an increase in response rate, but signaled no change in frequency of reinforcement, only 50% of their rats showed peak shift. On the basis of the results reported in Phase 1 of the present study, we predict that if Huff et al. ran a group of rats for which S_1 was discriminative for response increase while signaling a decrease in reinforcement, peak shift would not have been forthcoming.

Inhibition and the peak shift. Spence's (1937) theoretical treatment of transposition has frequently been used to explain generalization peak shift (Hearst, 1968; Rilling, 1977). He postulated that transposition results from the summation of separate gradients of excitation and inhibition and is thus dependent on S_2 acquiring inhibitory control relative to S_1 . The question, then, concerns the sources of inhibition. There has been some recent speculation that operant and Pavlovian inhibition can be separately identified and that they both contribute to inhibitory stimulus control (Gutman, 1977; Rilling, 1977; Weiss, 1978). The operant inhibition would be based on a negative contingency between a response and a reinforcer, whereas the Pavlovian inhibition would be produced by a negative contingency between a stimulus and a reinforcer. If this is the case, inhibition should be more pronounced if both factors are operating in concert than if only one factor is operating. Gutman (1977) demonstrated this using a combined-cues test. In his experiment responding was significantly more suppressed by a stimulus correlated with decreases in both response and reinforcement rates than by one correlated with only a decrease in responding.

Although less definitive than a summation test, another way of assessing inhibitory stimulus control is through the slope of a U-shaped generalization gradient after interdimensional discrimination training (Jenkins, 1965). Gutman (1977) used extinction (correlated with

response and reinforcement reduction) to generate his most powerful inhibitor. A variable-time (VT) schedule (correlated only with response reduction) generated an inhibitor that produced more moderate suppression on a combined-cues test than the suppression produced by a stimulus correlated with extinction. When Weisman and Palmer (1969, Experiment 2) reinforced responding in the presence of a green key and extinguished it when a white vertical line was superimposed, steep U-shaped gradients were produced in a line orientation generalization test. In comparison, when responding was reduced to the white line by a VT schedule, the slope of the U-shaped gradient was more shallow (Weisman & Ramsden, 1973, Experiment 2). Thus, on a combined-cues test as well as on a generalization test, when response and reinforcement variables were acting in concert, inhibition was strengthened. The test findings of the present experiment agree with this observation. Only 5.5% of the gradient area was located beyond S_2 when S_2 was correlated with extinction (Phase 2), whereas 28.9% was contained beyond S_2 in Phase 2 when S_2 was correlated with a decrease in response and an increase in reinforcement (Table 4). The capacity to inhibit responding generalized beyond S_2 in Phase 2 but not in Phase 1.

According to Spence's gradient interaction hypothesis, if S_2 is not an inhibitor, peak shift should not occur, as indeed it did not in Phase 1 of the present experiment. This is consistent with the position taken by Weiss (1978), further elaborated here, that little inhibition should be produced by a low-rate schedule condition when $R-S^R$ and $S-S^R$ contingencies are in conflict, as they were in Phase 1. We need an independent determination of the stimulus control generated by the DRO condition on a chain VI DRO schedule. Pigeons could be trained on a chained schedule where responding on a green key produced a white vertical line during which reinforcements were presented contingent upon subsequent nonresponding. Here, where the vertical line would be associated with a response decrease and reinforcement increase, we predict an essentially flat line-tilt gradient.

Blough (1975) has suggested a neoSpencian model of generalization that assumes "that trials with stimuli in a set have consequences (food reinforcement for example) that modify

the probability of response in the presence of the stimuli according to a linear equation" (p. 4). This assumption of response and reinforcement covariation makes the model inapplicable to the present experiment. The probability of treadle pressing in S_1 was roughly comparable in both phases of this experiment, in spite of the fact that S_1 was correlated with a decrease in reinforcement in Phase 1 and an increase in Phase 2. Hence the present data suggest that a second factor would have to be added to Blough's model to handle those situations where response and reinforcement factors do not covary, and when they are in conflict.

Respondent Key Pecks

In Phase 1 of this study, key pecks were elicited during S_2 , where grain was presented on a DRO schedule, at an average rate of over 60 pecks per min. During the chain VI component (S_1) on the schedule, only three key pecks per min were elicited. In spite of this 20:1 discrimination in rate between S_1 and S_2 , key-peck gradients were approximately symmetrical and sharply peaked at S_2 , the stimulus value that elicited pecking in training. This narrow symmetrical gradient around S_2 would not be anticipated by Spence's model if S_1 , which signaled no food, was inhibitory.

Excitatory and inhibitory gradients for auto-shaped pecks following interdimensional discrimination training have been reported (Tomie, Davitt, & Engberg, 1976; Wessells, 1973). In addition, Wessells found that in a discriminated autoshaping procedure, the $S-$ does acquire inhibitory control as revealed by retarded autoshaping in the presence of the previous $S-$ and by suppression of responding on a combined-cue test. The low rate of elicited key pecking during the S_1 (food-reinforced) component in Phase 2 of the present study is probably an example of this retardation of acquisition, since S_1 signaled the absence of food in Phase 1. Comparable retardation has also been shown in salivary conditioning by Konorski and Szwedkowska (1952). Given that all this evidence indicates that S_1 in Phase 1 should have been an inhibitor of elicited key pecks, where does this leave us in the application of the gradient interaction analysis to our findings?

Spence's theory was originally formulated to explain transposition in a two-choice oper-

ant discrimination problem. When peak shift has been reported, it has almost exclusively been after operant discrimination training. A few studies have explored peak shift following classical conditioning, and these have not been successful in establishing the phenomenon within that paradigm. For example, following discrimination training in classical conditioning, reliable peak shift has been obtained only when $S+$ was a higher frequency tone than $S-$ (Hupka, Liu, & Moore, 1969; Liu, 1971; Moore, 1972), suggesting that intensity dynamism might have been operating (Gray, 1965; Hull, 1949). In the one study that established differential autoshaping in an intradimensional line-tilt discrimination, peak shift was not obtained on a line-tilt generalization test (Nallan, McCoy, Pace, & Welch, 1979). This failure supports previous findings in the classical conditioning paradigm as well as those of the present experiment. Unfortunately, Nallan et al. did not have a comparison group that formed this discrimination through an operant contingency, an important control in light of previous difficulties in obtaining peak shift on a line-tilt dimension (Hearst, 1968, 1971). A direct comparison of key-peck gradients after multiple VI EXT and multiple VT EXT with the stimulus parameters employed in the present experiment would be informative. On the basis of the research currently available, we are forced to conclude that generalization peak shift does not readily occur after intradimensional discrimination training in classical conditioning. This apparent difference in the discriminative processes operating in operant and classical training is a notable exception to the many parallel phenomena revealed within these two learning paradigms (Kimble, 1961; Mackintosh, 1974).

CONCLUSIONS

The results reported in the present experiment, supported by those of Huff et al. (1975) and related research by Terrace (1968, Experiment 3) and Yarczower et al. (1968), confirm the application of a two-process approach like that described by Weiss (1978) in furthering our understanding of the variables contributing to the peak shift. According to this approach, the negative S_1 -reinforcement relation in Phase 1 operated against our obtaining peak shift on the treadle, due to the influence of a

"central motive state," like that postulated by Konorski (1967) and by Rescorla and Solomon (1967), on the operant response. Further, although an increase in operant rate in S_1 , relative to that in S_2 , is adequate to produce peak shift even when S_1 is not differentially correlated with reinforcement, a positive S_1 - S^R contingency enhances the likelihood of obtaining peak shift.

Further, the findings of the present experiment suggest how R - S^R and S - S^R contingencies might contribute to the development of inhibition to S_2 . Through this extension, the two-process model can be employed in applying Spence's gradient interaction interpretation to generalization peak shift in the instrumental situation.

Autoshaped key pecks as well as operant treadle presses were monitored. In spite of the clear respondent discriminations formed in Phase 1 and the minimal likelihood of interference between the operant treadle presses and elicited key pecks that occurred in different components of the chained schedule (Bushnell & Weiss, 1980), the gradients for these elicited responses were narrow and sharply peaked at the food-correlated stimulus. This failure to obtain peak shift for a classically conditioned response is consistent with the results of previous attempts and suggests a difference between operant and respondent discriminative processes. Although the stimulus-reinforcer correlation appears to contribute to the likelihood of peak shift occurring in the operant situation, as established through classical procedures, this correlation seems inadequate to generate peak shift for the elicited response.

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