INTERACTIONS IN MULTIPLE SCHEDULES WITH DIFFERENT RESPONSES IN EACH OF THE COMPONENTS¹

JOHN SCULL² AND R. F. WESTBROOK³

UNIVERSITY OF SUSSEX

Pigeons were exposed to multiple schedules in which a key was lit in one component and a bar was present in the other. Ten subjects were trained to peck the key and to press the bar with their feet, and four subjects were trained to peck both the bar and the key. After a period of exposure to variable-interval reinforcement in both components, subjects were exposed to extinction in one component. Only one of the 10 pigeons in the key-peck:bar-press condition showed an increase in rate in the other component, while seven of them showed a decrease. In the key-peck:bar-peck condition, three of the four subjects showed positive contrast. The data suggest that a condition for contrast to occur is that topographically similar behaviors be required in both components of the multiple schedule.

Interactions in multiple schedules, in which different stimuli successively signal different experimental conditions, refer to the changes in response rate in one component that take place as a consequence of changes in the reinforcement conditions in the other component. Perhaps the most intensively studied interaction is positive contrast, in which response rate in the constant component varies in the opposite direction from rate in the changed component (Reynolds, 1961). Most experiments on contrast have investigated the effects of changes in the reinforcement schedule in one component upon response rate in the other, constant, component. Apart from this, however, there has been little attempt to delimit the boundaries of the effect.

Premack (1969) pointed out the unlikelihood that every reinforcement schedule to which an organism is exposed will interact with every other reinforcement schedule that

it has experienced. In other words, there may be multiple schedules in which positive contrast does not occur. One possible limit on the occurrence of positive contrast lies in the operants employed in the components of the multiple schedule: interactions obtained when different responses are required in each of the components may differ from those obtained when, as is usually the case, the same response is required in both of the components.

Premack (1969) trained rats in a multiple wheel-running:bar-pressing schedule and found that changes in one component produced changes in the rate of bar pressing measured during different sessions on the same day. However, Premack's procedure was complex and only one rat showed positive contrast, while the other two showed little change in rate. Further clarification of the effects of the response topography requirement is desirable.

The present experiments examined the occurrence of positive contrast with pigeons as subjects and with pecks on a key and foot presses of a bar the responses required in the multiple schedule.

EXPERIMENT 1

METHOD

Subjects

Six male, hybrid pigeons were maintained at 80% of their free-feeding weights. In their prior experimental history, foot presses of a

¹This work was conducted while the first author held a Canadian National Research Council fellowship and the second author held a United Kingdom Science Research Council studentship at Sussex University. The authors are grateful to N. S. Sutherland, Head of the Laboratory of Experimental Psychology, for the provision of facilities. Preparation of this manuscript was facilitated by a U. S. Public Health Service grant to L. J. Kamin of Princeton University.

²Now at Cedar Lodge Residential Centre, Cobble Hill, British Columbia, Canada.

³Reprints may be obtained from R. F. Westbrook, Department of Psychology, Princeton University, Princeton, New Jersey 08540.

bar had been reinforced on a variety of multiple schedules, the component stimuli of which had been a noise and a tone.

Apparatus

A standard pigeon chamber 30 by 30 by 30 cm was used. A lever 8 by 4 by 0.5 cm was attached to the stimulus panel 7 cm from the floor and 3 cm from the side wall. The lever projected into the box for 4 cm and at a slightly downward angle. The pressure required to operate the lever was 0.12 N. The lever was retractable. A light behind the panel reflected off the bar and was lit whenever the bar was in the chamber. A response key of translucent plastic, 2 cm in diameter and 20 cm above the floor, was mounted on the stimulus panel above a grain hopper. The visual stimulus was provided by a miniature light bulb (2.5 W Vitality type $\times$ 599 cs) located in a housing behind the key. Heavy duty relays behind the stimulus panel provided auditory feedback for responses to the key and to the bar. A white houselight was centered at the top of the wall opposite the response panel. The chamber was located inside a sound-attenuating cubicle and masking noise was continuously present. The experiments were controlled by conventional electromechanical equipment.

Reinforcement Scheduling

Reinforcement was 5-sec access to a tray of mixed grains. The operation of the tray was accompanied by illumination of the magazine. During reinforcements, responses were ineffective and were not recorded; also, the component time count was stopped. Reinforcements were arranged on a variable-interval 1-min schedule (VI 1-min). The values of the 16 intervals used were derived from Fleshler and Hoffman (1962).

Training Procedure

Components of 30-sec duration were separated by 10-sec blackouts during which the keylight was off, the bar was retracted, and the houselight was off. A reinforcement that was scheduled but not collected by the end of a component was cancelled by the blackout. There were 97 components in a daily session and at least six sessions per week. The key-pecking and bar-pressing components alternated in an irregular sequence: when the key

was lit, the bar was absent; and when the bar was present, the key was darkened.

Throughout the experiment, the pigeons were frequently observed through a peephole in the experimental cubicle, which revealed that the bar-pressing response was being executed by the foot with the bird in a fully erect position. The way the pigeons were trained to make this response has been described by Westbrook (1973).

Earlier experiments had shown that the minimum duration of a bar-press response was well over 0.1 sec while a bar peck, including hysteresis in the bar, was always of a shorter duration. To ensure that the subjects were not pecking the bar in the experimenter's absence, responses shorter and longer than this duration were recorded separately, and reinforcements were delivered only after the bar had been depressed for at least 0.1 sec. Very few responses shorter than this criterion were observed during the experiment. The experiment involved two stages. In Stage 1, there were 13 sessions of *mult* VI 1-min VI 1-min and in Stage 2, 15 sessions of *mult* VI 1-min extinction (EXT).

RESULTS

Performance on key pecking and bar pressing over the last five sessions of baseline training for each subject and the assignment of subjects to conditions are shown in Table 1. Also included in this table, are the highest and lowest response rates for each subject in the component correlated with the VI schedule during Stage 2. All subjects were showing fairly stable response rates by the end of *mult* VI 1-min VI 1-min, the rate of key pecking being much higher than the rate of bar pressing. However, there was little difference between the rates of reinforcement in the two components. To present rates of both operants in the same panels, response rates in the second stage relative to the medians of the first-stage scores presented in Table 1 were computed and are shown in Figure 1.

Figure 1 shows that a rapid reduction in rate of responding occurred for all subjects in the extinction component. Of the subjects for which the VI schedule continued on key pecking, responding increased slightly in Subject 1788, decreased slightly in Subject 1790, and did not change in Subject 1789. Of the subjects for which the VI schedule continued on bar

Table 1

Responses per minute in both components in Experiment 1 for the last five sessions of *mult* VI 1-min VI 1-min training and the assignment of subjects to Stage 2 conditions of reinforcement are shown. Also included is the highest and lowest rate reached by each subject in the VI 1-min component in Stage 2.

<i>Subject</i>	<i>Session</i>	<i>Key Rate</i>	<i>Bar Rate</i>	<i>Stage 2 Conditions of Reinforcement</i>
1788	9	109.1	3.1	Key Peck (VI 1-min) Bar Press (EXT)
	10	126.8	4.2	
	11	91.5	4.1	
	12	94.9	9.8	
	13	112.1	8.4	
highest	6	152.7		
lowest	10	110.0		
1789	9	122.0	5.3	
	10	113.8	11.9	
	11	103.1	7.2	
	12	104.2	5.6	
	13	115.3	1.8	
highest	11	119.5		
lowest	7	91.0		
1790	9	56.2	10.9	Key Peck (VI 1-min) Bar Press (EXT)
	10	79.6	9.6	
	11	104.7	10.8	
	12	110.2	10.6	
	13	96.1	18.4	
highest	5	96.6		
lowest	2	59.6		
1791	9	93.7	5.7	
	10	81.7	11.3	
	11	73.9	13.2	
	12	66.1	13.6	
	13	69.2	12.0	
highest	1		9.5	
lowest	7		3.7	
1792	9	167.1	15.6	Key Peck (EXT) Bar Press (VI 1-min)
	10	165.7	20.8	
	11	170.5	14.3	
	12	177.0	14.8	
	13	167.0	16.9	
highest	1		11.7	
lowest	15		4.2	
1793	9	110.3	12.3	
	10	109.3	17.7	
	11	109.8	14.8	
	12	94.9	15.0	
	13	94.7	14.7	
highest	3		17.8	
lowest	4		7.7	

pressing, responding decreased in all three subjects.

EXPERIMENT II

Experiment 1 found little evidence for positive contrast, and when reinforcement of key

pecking was discontinued, negative induction of bar pressing was observed. Because these results differ in many respects from those obtained with the same operant in both components, four additional subjects were studied in the multiple key-peck:bar-press condition in Experiment II.

Fig. 1. Response rates during the *mult* VI EXT stage relative to the median response rates in the *mult* VI VI stage in Experiment 1. For the three subjects on the left, the bar-pressing component was associated with EXT; for the three subjects on the right, the key-pecking component was associated with EXT.

Experiment 1 differed from most contrast experiments in that not only were different responses required in the two components but also different manipulanda were employed in each component and the presence of these manipulanda constituted the discriminative stimuli for appropriate responding. This may have had the effect of facilitating response reduction in the extinction component, a condition that may not lead to much positive contrast (Hearst, 1969; Terrace, 1966). Therefore, four subjects in Experiment 2 were trained to peck both the key and the bar. These four subjects differed from the other four only in the required response topography. The physical stimulus situations for the two groups were identical.

METHOD

Subjects

Eight adult, male, hybrid pigeons without prior experimental histories were maintained at 80% of their free-feeding weights.

Training Procedure

The procedure was the same as in Experiment 1 with the following exceptions: (1) in the bar-press:key-peck condition, bar presses shorter than 0.1-sec duration were reinforced so that the bar-pressing and bar-pecking contingencies would be comparable; (2) components were of 60-sec duration rather than 30 sec; (3) 33 components were presented in each session rather than 97.

Observation of the bar-press:key-peck subjects indicated that, as in Experiment 1, bar presses were executed by the foot with the animal in an erect position while subjects in the bar-peck:key-peck group pecked the bar with a downward motion of the head from an almost horizontal body position.

The experiment involved two stages. In Stage 1, there were 32 sessions of *mult* VI 1-min VI 1-min and in Stage 2, 20 sessions of *mult* VI 1-min EXT.

RESULTS

Bar and key response rates over the last five sessions of *mult* VI 1-min VI 1-min for each subject, the allocation of subjects to the conditions of responding, and the conditions of reinforcement in Stage 2 are shown in Table 2. Also included in this table, are the highest and lowest rates reached by each subject in the

component correlated with the VI schedule during Stage 2.

Figure 2 shows rates of responding in the *mult* VI EXT stage relative to the medians of the baseline values for each subject in the bar-press:key-peck condition.

In general, rates of reinforcement for bar pressing and key pecking were similar but rates of bar pressing were much less stable than comparable rates in Experiment 1. This may have been due to any of the procedural differences, but it was probably because these subjects did not have an extended history of bar-press training before the start of multiple bar-press:key-peck training. However, Subjects 96 and 97 generally replicated the effects found in Experiment 1: reduction of response rate in the extinction component, and negative induction in the component that continued on VI. The induction was greater when measured on bar pressing (Subject 96) than when measured on key pecking (Subject 97). Subjects 94 and 95 did not respond differentially in the two components: in Subject 94, rate in both components increased; in Subject 95, rate in both components decreased.

Figure 3 shows rates of responding in the *mult* VI EXT stage relative to the median baseline values for each subject in the bar-peck:key-peck condition. All four subjects showed greatly reduced response rates in the extinction component. Three of the four subjects showed positive contrast in the component that remained on VI, with the effect being large in Subject 99. The fourth subject, #70 showed less reduction in responding in the extinction component, and little change in rate in the VI component until about Session 18, after which the rate was lower than in the *mult* VI VI stage.

DISCUSSION

For eight of the 10 subjects exposed to the multiple key-peck: bar-press schedule rates of responding were reduced much more in the extinction component than in the VI component. Of these eight, only one showed even a small positive contrast effect. On the other hand, three of the four subjects exposed to the multiple key-peck: bar-peck schedule did show positive contrast, with one subject showing a very large effect. That is, when pecks were required in both components of the multiple

Table 2

Responses per minute in both components in Experiment 2 for the last five sessions of *mult* VI 1-min VI 1-min. The assignment of subjects to conditions of responding and to the Stage 2 conditions of reinforcement are shown. Also included is the highest and lowest rate reached by each subject in the VI 1-min component in Stage 2.

<i>Subject</i>	<i>Session</i>	<i>Key Rate</i>	<i>Bar Rate</i>	<i>Conditions of Responding</i>	<i>Stage 2 Conditions of Reinforcement</i>
94	28	52.8	18.1		
	29	49.2	14.0		
	30	63.6	16.0		
	31	57.5	10.4		
	32	46.1	14.5		
highest	15	92.4		Key Peck	(VI 1-min)
lowest	5	63.4		Bar Press	(EXT)
97	28	53.7	2.41		
	29	46.1	0.12		
	30	60.3	4.38		
	31	68.3	5.8		
	32	71.5	14.8		
highest	1	79.6		Key Peck	(VI 1-min)
lowest	19	24.1		Bar Press	(EXT)
95	28	64.8	10.0		
	29	71.3	12.2		
	30	90.4	15.5		
	31	83.9	6.5		
	32	80.0	11.3		
highest	16		17.5	Key Peck	(EXT)
lowest	20		0	Bar Press	(VI 1-min)
96	28	21.2	7.9		
	29	17.8	5.0		
	30	11.2	10.5		
	31	18.1	8.9		
	32	19.9	9.8		
highest	9		10.7	Key Peck	(EXT)
lowest	8		1.8	Bar Press	(VI 1-min)
70	28	89.8	21.3		
	29	65.5	7.3		
	30	94.4	13.4		
	31	70.3	27.0		
	32	44.3	27.1		
highest	8	36.6		Key Peck	(VI 1-min)
lowest	1	30.1		Bar Peck	(EXT)
93	28	39.3	41.7		
	29	36.7	46.7		
	30	39.1	59.9		
	31	37.9	66.0		
	32	50.0	59.2		
highest	3	72.3		Key Peck	(VI 1-min)
lowest	17	11.7		Bar Peck	(EXT)
21	28	112.6	129.7		
	29	97.9	91.8		
	30	89.4	103.1		
	31	84.7	105.8		
	32	64.6	28.1		
highest	11		134.0	Key Peck	(EXT)
lowest	6		88.7	Bar Peck	(VI 1-min)
99	28	106.6	63.1		
	29	90.1	37.0		
	30	76.3	49.0		
	31	72.0	62.0		
	32	77.3	69.1		
highest	9		148.7	Key Peck	(EXT)
lowest	2		111.6	Bar Peck	(VI 1-min)

Fig. 2. Response rates during the *multi* VI EXT stage relative to the median response rates in the *multi* VI VI stage for the four subjects in the key-peck:bar-press condition. For the two subjects on the left, the bar-pressing component was associated with EXT; for the two subjects on the right, the key-pecking component was associated with EXT.

schedule, contrast was obtained under conditions that did not typically produce contrast in the key-peck:bar-press condition.

An account of contrast that held that suppression of a response increased the strength of that same response in the presence of different stimuli would explain both the present results and much of the earlier work on contrast (*e.g.*, Halliday and Boakes, 1972). This suggestion, of course, is the opposite of the "generalization of inhibition" mechanism proposed in classical discrimination learning theory (Spence, 1937). According to such an account, contrast should occur when responses have enough similar components to allow summation of response strengths. In multiple sched-

ules with different responses in the two components, extinction of one response should increase the subject's tendency to perform that response in the other component. This should produce response competition and reduce rate in the constant component.

There was an apparent asymmetry in the induction effects obtained in these experiments, such that more induction was found when bar pressing was the response in the constant component. Recent observations of superstitious responding have suggested that behavior related to key pecking occupies an especially strong position for pigeons receiving food reinforcement (*e.g.*, Staddon and Simmelhag, 1971). A reasonable inference on the basis of

Fig. 3. Response rates during the *mult* VI EXT stage relative to the median response rates in the *mult* VI VI stage for the four subjects in the key-peck:bar-peck condition. For the two subjects on the left, the bar-pecking component was associated with EXT; for the two subjects on the right, the key-pecking component was associated with EXT.

these results is that an enhanced tendency to key peck might easily interfere with other responses such as bar pressing, while key pecking may be uniquely resistant to interference from other response tendencies.

There is evidence that positive contrast does not occur in multiple schedules with pigeons bar pressing in both components (Westbrook, 1973). This finding presents a problem for the analysis given here and raises questions concerning the generality of the present results. The present analysis could be modified to account for the failure to observe contrast when bar pressing is the required response in both components of the multiple schedule by supposing that the criterial response of a key closure occupies a high position in the complex of

behaviors involved in key pecking by comparison with the criterial response of bar pressing, which occupies a low position in the complex of behaviors involved in pressing the bar. Given either an asymptote of strength that the complex of behaviors can reach or a limited period of time over which contrast-producing effects last, then suppression of the key-pecking complex should summate on key closures at the expense of the other behaviors in the complex, whereas the reverse should be the case for the criterial response of a bar closure. However, the generality of the present results is questioned by the failure to observe contrast when bar pressing is the response in both components. Suppose there was a response currently available in the pigeon other than peck-

ing and other than bar pressing with which, when employed in both components of a multiple schedule, contrast occurred. This might mean that had key pecking in the present studies been alternated with such a response, then extinction of this response could have produced contrast on key pecking. Such a result would clearly weaken the present account because it would suggest that the failure to observe contrast on key pecking in the key-peck: bar-press condition was due to some factor involved in the failure to obtain contrast on bar pressing, rather than to different responses being employed, as is required by the present account.

REFERENCES

- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 529-530.
- Halliday, M. S. and Boakes, R. A. Discrimination involving response-independent reinforcement: Implications for behavioral contrast. In R. A. Boakes and M. S. Halliday (Eds.), *Inhibition and learning*. New York: Academic Press, 1972. Pp. 73-97.
- Hearst, E. Extinction, inhibition and discrimination learning. In N. J. Mackintosh and W. K. Honig (Eds.), *Fundamental issues in associative learning*. Halifax: Dalhousie University Press, 1969. Pp. 1-41.
- Premack, D. On some boundary conditions of contrast. In J. T. Tapp (Ed.) *Reinforcement and behavior*. New York: Academic Press, 1969. Pp. 120-145.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 57-71.
- Spence, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychological Review*, 1937, 44, 430-444.
- Staddon, J. E. R. and Simmelhag, V. L. The "superstition" experiment: a reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, 78, 3-43.
- Terrace, H. S. Stimulus control. In W. K. Honig (Ed.) *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 271-344.
- Westbrook, R. F. Failure to observe positive contrast when pigeons press a bar. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 499-510.

Received 9 August 1972.

(Final Acceptance 2 July 1973.)