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THE ROLE OF ELICITED RESPONDING IN BEHAVIORAL CONTRAST[1]

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An attempt was made to separate operant and elicited pecks occurring in multiple schedules of food reinforcement by moving the component stimuli to a second key, upon which pecks had no effect. The operant key stimulus was constant, regardless of the reinforcement schedule in effect. Experiments included two- and three-component multiple schedules and a comparison of the single-key and the two-key procedures. In general, conditions that typically produce positive contrast in single-key procedures reduced responding to the constant-stimulus key (induction) and increased responding to the component-stimulus key (contrast) in the two-key procedure. The results were interpreted as supporting the contention that two response classes, operant and elicited, are present in standard multiple schedules. In addition, elicited responses were strongly implicated in contrast phenomena.

Recent experiments on pigeons' key-peck responding suggest that two distinct response classes may be confounded in standard operant procedures, especially when stimuli signalling different reinforcement rates are involved. Brown and Jenkins (1968) demonstrated that pigeons will peck a key illuminated a few seconds before the presentation of food, and Williams and Williams (1969) showed that such "autoshaped" pecking will continue even when it prevents food delivery (negative automaintenance). When pecking prevents food, pecks are never immediately reinforced. Such pecks, therefore, appear to be elicited by the stimulus. Schwartz and Williams (1972) measured response duration under these two autoshaping procedures and found them to be shorter when pecking prevented food delivery than when pecking had no effect upon food delivery. They also found that short-duration pecks could not be differentially reinforced, while long-duration pecks could. These studies suggest that, besides operant pecks, or pecks controlled by the response-reinforcer contingency, there is a second, elicited class of pecking responses, or pecks directed at stimuli paired with food reinforcement. Presumably, only elicited pecks are present in negative automaintenance situations, while both elicited and operant pecks may be present in positive automaintenance situations, since in that procedure there is no guarantee against accidental correlations of responses and reinforcement.

Other studies have assessed the conditions under which elicited pecking occurs (Gamzu and Schwartz, 1973; Gamzu and Williams, 1973; Schwartz, 1973; Ricci, 1973). Apparently, the alternation of two stimuli, one of which is correlated with a higher rate of reinforcement than the other, is a sufficient condition for the development of elicited pecking. Gamzu and Schwartz, for example, reported pecking elicited by a multiple schedule of response-independent reinforcement. Pigeons pecked the key when it signalled food availability on a variable-time schedule. Pecking could not have been maintained solely by the occasional pairing of pecking and food presentation, since pecking declined when both components of the multiple schedule produced the same rate of reinforcement.

The conditions that have been shown to generate elicited pecking are also present in multiple schedules of response-produced reinforcement, when the different components produce different rates of reinforcement. Thus, both operant and elicited pecks may be involved in the total response output on such schedules. In the usual experiment, the component stimuli are projected directly on the response key. Any elicited pecks would be di-

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rected to this key and recorded along with operant pecks. For example, after a multiple variable-interval 1-min variable-interval 1-min (*mult* VI 1-min VI 1-min) schedule is changed to multiple variable-interval 1-min extinction (*mult* VI 1-min EXT), the key illumination associated with the first component signals a higher rate of reinforcement than that of the second. This is a condition that generates elicited pecking, and it is also the condition that typically produces positive contrast, *i.e.*, an increase in the rate of first-component VI responding above the previous *mult* VI VI baseline (Reynolds, 1961). Contrast produced by a change to *mult* VI EXT, as Gamzu and Schwartz (1973) and Ricci (1973) suggest, might simply be the addition of elicited pecks to the operant baseline.

The present procedure was designed to evaluate the role of elicited pecking in contrast phenomena by separating operant and elicited pecks experimentally. The procedure relies upon the different controlling variables in the two cases. Elicited pecks are assumed to be directed to stimuli paired with reinforcement, while operant pecks are presumably directed to wherever they produce reinforcement. Although the stimuli correlated with a reinforcement schedule are usually projected upon the operant key, there is no reason why component stimuli could not be projected elsewhere. Stimulus control of operant responding should develop regardless of the locus of the component stimuli. The present experiments used multiple schedules with the component stimuli displaced from the operant key to a second key. Pecks on this second key had no effect in producing food. It was assumed that operant pecks would remain directed to the first key and that elicited pecks would be directed to the second key.

EXPERIMENT 1: SEPARATION OF ELICITED AND OPERANT PECKS ON A TWO-COMPONENT MULTIPLE SCHEDULE

METHOD

Subjects

Three adult, male, White Carneaux pigeons were maintained at about 80% of their free-feeding weights. Their experimental experience included various schedules of positive reinforcement and schedule-elicited aggression. None of the pigeons was experienced with autoshaping procedures.

Apparatus

The right key of a three-key experimental chamber was covered with a metal plate. The remaining two keys were 19 mm in diameter and were 75 mm apart, center-to-center. The keys were transilluminated with either a red or green light or three vertical white lines on a black background, projected by a Grason-Stadler E4580 Multiple Stimulus Projector unit. The food hopper was located directly below the center key. During reinforcement, a 3-sec presentation of mixed grain, the food-hopper light was on and the keylights were out. White noise was fed continuously into the chamber, and the houselight, a 6-W bulb attached to the right-hand corner of the response panel, was lit throughout the experimental session. Events were scheduled with standard electromechanical switching circuitry located in an adjoining room.

Procedure

a. *Two-key procedure.* The pigeons were exposed to a two-component multiple schedule with the following specifications. The center key was illuminated constantly with three vertical white lines on a black background. This key will be referred to as the constant key. The left key was illuminated with a green light during the first component, and with a red light during the second component. This key will be referred to as the stimulus key. During an extinction (EXT) component, pecks on either key had no effect. During a variable-interval (VI) component, pecks on either key exceeding about 0.14 N produced a feedback click from behind the response panel. Pecks on the constant key during a VI component produced food according to the VI schedule. Components alternated, with durations of either 1 or 2 min arranged randomly, and with a total exposure of 30 min for each component during each experimental session, excluding reinforcement time. The pigeons were studied daily, except for occasional weekends. The VI schedules were arranged by constant-probability tapes constructed according to the specifications of Catania and Reynolds (1968). A single tape scheduled reinforcements. When the schedule was *mult* VI VI, the tape continued to operate through component alternations. When the schedule was *mult* VI EXT or *mult* EXT VI, the tape stopped during EXT, and any reinforcements already scheduled were held until the next VI component.

The order of conditions and the number of sessions each was in effect were as follows: *mult* VI 30-sec EXT (33), *mult* VI 30-sec VI 30-sec (8), *mult* EXT VI 30-sec (12), *mult* VI 60-sec VI 60-sec (10), and *mult* VI 60-sec EXT (11).

b. *Alternation of single-key and two-key procedures.* After concluding procedure 1a, daily sessions of single-key *mult* VI 1-min VI 1-min, *mult* VI 1-min EXT, or *mult* EXT VI 1-min alternated with sessions of the same schedule, but with the component stimuli displaced to a second key, as in the first procedure. On two-key days, the stimuli were the same as in procedure 1a. On single-key days, the green and red component stimuli were superimposed upon the three vertical white lines on the center key. The left key remained dark throughout the session, and pecks on it had no effect. Alternation of stimuli, session length, and reinforcement time were as in 1a. Each condition lasted 12 sessions: a session of the single-key procedure was followed by a session of the two-key procedure, and so on, for a total of 12 sessions. The sequence of conditions was: *mult* VI 1-min VI 1-min, *mult* EXT VI 1-min, *mult* VI 1-min VI 1-min, *mult* VI 1-min EXT. Note that the second condition, *mult* EXT VI 1-min, was a reversal of the last condition of procedure 1a.

RESULTS AND DISCUSSION

The results of procedure 1a are shown in Figure 1, beginning with the twenty-fifth session of the first experimental condition. Although the three pigeons showed somewhat different patterns of responding, the displacement of the component stimuli to a second key eliminated permanent contrast effects from the constant key. That Pigeon 103 did not peck the stimulus key and did show some temporary contrast on the constant key suggests that the separation procedure was not completely successful in dissociating the elicited pecks from the constant key. That Pigeons 104 and 106 did not peck the stimulus key during *mult* VI VI, but did during *mult* VI EXT and *mult* EXT VI, suggests that pecks on this key were indeed elicited by the component stimuli and were not maintained by reinforcement for pecks on the operant key. Also, since pecks on the stimulus key occurred only when one of the components was EXT, the feedback clicks produced by responding on either key during VI could not have been maintaining pecks to the stimulus key.

Because the sum of pecks on the constant and stimulus keys for Pigeon 104 did not total to a contrast effect, and because Pigeon 103 showed a very low rate of stimulus-key pecking combined with temporary contrast on the constant key, it would be of some interest to know how great the contrast effect was for these pigeons on a single-key multiple schedule. The results of procedure 1b are presented in Table 1. Considering responding on single-key days only, the procedure was only partially successful in generating behavioral contrast, although the rate changes that did occur were in the expected direction.

Considering now the two-key sessions, as Table 1 shows, responding on the constant key following a change from *mult* VI VI to either *mult* EXT VI or *mult* VI EXT decreased for all three pigeons. Responding on the stimulus key shows the opposite tendency: responding to the VI component increased. An interesting anomaly occurred with Pigeon 106: during the second *mult* VI 1-min VI 1-min condition, responding on the stimulus key was almost as great as VI responding during the previous and following conditions.

When one of the components was EXT, the increased stimulus-key responding for Pigeons 103 and 104 did not compensate for the reduced constant-key responding, and the total responding on two-key days was less than responding on single-key days. For Pigeon 106, the sum of response rates on the stimulus and the constant keys exceeded the rates during single-key days.

A straightforward interpretation of the data suggests that contrast is a phenomenon of elicited and not operant responding. However, the present experimental technique might be confounding the conditions that produce contrast with those that displace elicited responses on the second key. The induction effect observed on the constant key in the present experiments might be the result of responses being shifted to the stimulus key when the conditions favorable for the redirecting of elicited responding are introduced, *i.e.*, when one

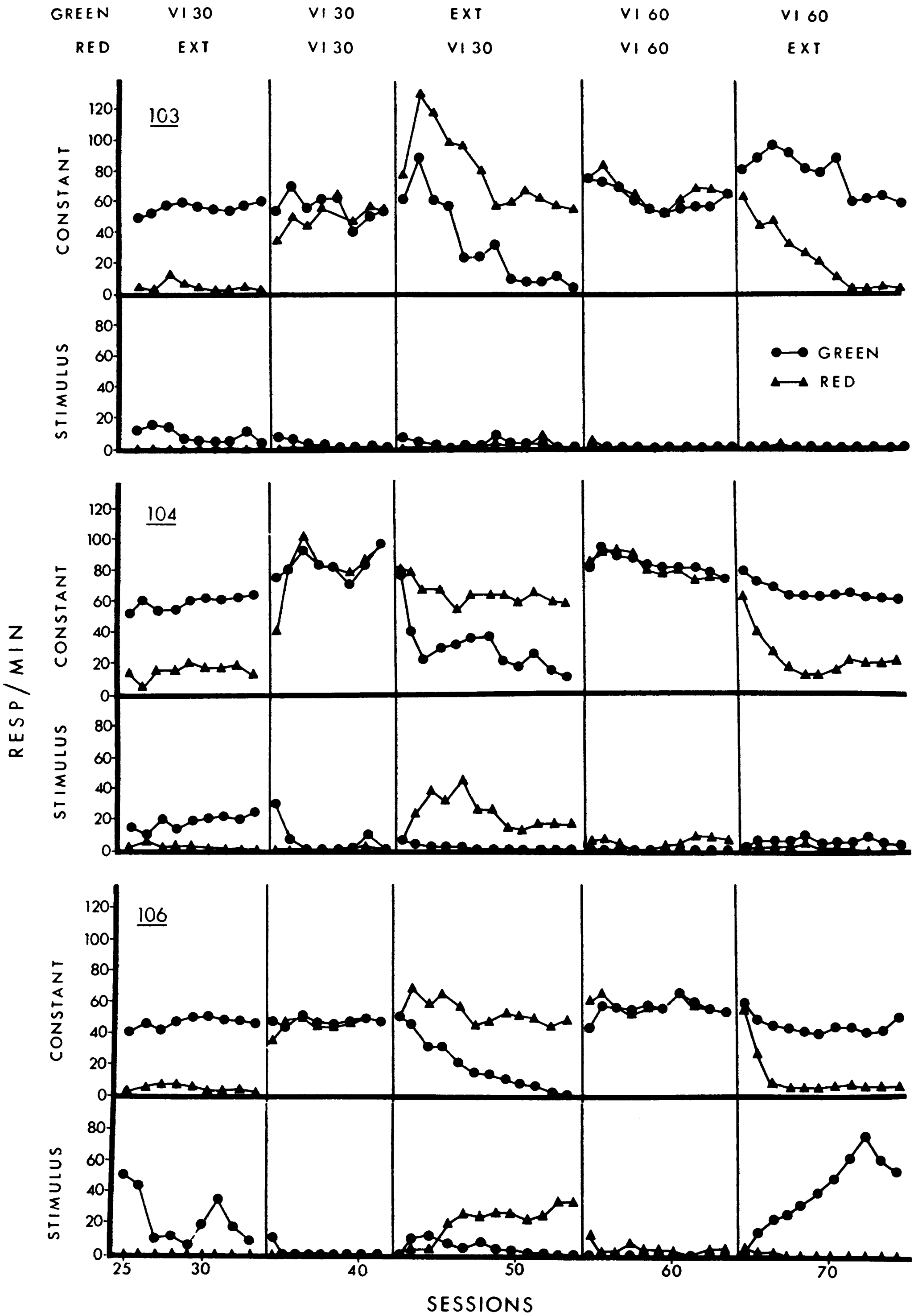

Fig. 1. Session-by-session responding by the three pigeons on the two-component multiple schedule of Experiment 1a. The top part of each graph shows constant-key responding in the green and red components, and the bottom part shows stimulus-key responding. The schedules in effect for each component are indicated at the top of the figure.

Table 1

Responses per minute (average last three sessions) in components 1 and 2 of the separation and single-key procedure of Experiment 1a.

	Separation Days						*Single-key Days*	
Schedule	*Constant Key*		*Stimulus Key*		*Total*			
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*
#103								
VI 1 VI 1	67.3	67.3	0.2	0.3	67.5	67.6	61.8	71.6
EXT VI 1	5.7	60.8	1.2	2.4	6.9	63.2	7.9	75.3
VI 1 VI 1	80.6	80.0	0.0	0.1	80.6	80.1	82.2	78.1
VI 1 EXT	61.8	13.2	2.3	3.6	64.1	16.8	86.1	7.6
#104								
VI 1 VI 1	89.2	90.3	0.6	0.7	89.8	91.0	76.0	79.7
EXT VI 1	15.3	65.1	0.6	11.0	15.9	76.1	8.9	107.1
VI 1 VI 1	81.8	82.0	0.7	0.6	82.5	82.6	83.9	95.5
VI 1 EXT	52.7	10.7	8.0	1.0	60.7	11.7	99.1	7.3
#106								
VI 1 VI 1	44.0	46.0	18.6	10.5	62.6	56.5	46.1	51.9
EXT VI 1	8.5	40.5	2.9	66.3	11.4	106.8	11.3	78.1
VI 1 VI 1	48.0	53.8	49.6	31.0	97.6	84.8	60.1	72.5
VI 1 EXT	47.8	5.0	51.9	0.8	99.7	5.8	61.1	3.9

of the component stimuli signals a higher rate of reinforcement than the other. This removal of a large number of responses from the constant key might be obscuring whatever else might occur to operant responding, *e.g.*, contrast.

Experiment 2 attempted to assess whether the contrast effect observed in single-key experiments is completely accounted for by changes in the rate of elicited responding, or whether the present results are better explained by appealing to some combination of changes in operant rate and the simultaneous displacement of elicited responding to the second key. Essentially, the procedure created the conditions favorable for the displacement of elicited pecks to a second key *before* creating the conditions that produce contrast. The procedure was similar to that in the first experiment, except that a three-component multiple schedule was used with at least one component being extinction. Because one or both of the remaining component stimuli were associated with a high rate of reinforcement, the essential conditions were always present for directing elicited pecks away from the constant key to the stimulus key. With one of the component stimuli EXT, the other two component stimuli could be either VI VI, VI EXT, or EXT VI. The latter two conditions should produce positive contrast with respect to the first, variable-interval variable-interval, baseline.

EXPERIMENT 2: SEPARATION OF ELICITED AND OPERANT PECKS ON A THREE-COMPONENT MULTIPLE SCHEDULE

METHOD

Subjects

Three adult, male, White Carneaux pigeons were maintained at about 80% of their free-feeding weights. All were experienced on simple schedules of positive reinforcement in an undergraduate laboratory course, but naive to autoshaping procedures.

Apparatus

The experimental chamber contained two 19-mm diameter keys, separated 65 mm center-to-center. The keys were illuminated from behind with colored Christmas tree bulbs. The food hopper was centered below the two keys. During reinforcement, a 3-sec presentation of mixed grain, the keylights were out, and the food-hopper light was turned on. The chamber was illuminated throughout the session by two small, white 6-W bulbs located on the left and right upper corners of the response panel. White noise was fed continuously into the chamber.

Procedure

The pigeons were exposed to a three-component multiple schedule with the component stimuli displaced to the second key. The left key, the constant key, was illuminated with white light throughout the session. The right key, the stimulus key, was illuminated with amber light during the first component, blue light during the second component, and green light during the third component. Component durations were 1 min, and components were presented in repeated cycles of the same order for a total of 60 min each session, excluding reinforcement time. During EXT, pecks on either key had no effect. During a VI component, pecks on both keys exceeding about 0.14 N produced a feedback click, and pecks on the constant key produced reinforcement on the VI schedule. The first component was always VI 1-min while the second and third components were either VI 1-min and EXT, EXT and VI 1-min, or EXT and EXT. The VI schedules were arranged with constant-probability tapes. Except for the first condition, each condition was in effect for about 10 sessions. The order of conditions, and the number of sessions for each, are reported with the results in Table 2.

RESULTS AND DISCUSSION

Table 2 presents the average rates of responding for the last five sessions in each condition. All three pigeons pecked the stimulus key during the first component, which was always VI 1-min, although Pigeon 128 began pecking only after the first few conditions. The pigeons rarely pecked the stimulus key when the key color signalled EXT. The rate of stimulus-key pecking during the second and third components, when either of these was VI, was erratic, and sometimes did not occur at all.

The important results are the rates of responding on the two keys during the first VI component as a function of the reinforcement conditions in the second and third components. Figure 3 summarizes these results and allows the patterns of contrast and induction to be seen more easily. The general effect upon constant-key responding of the change from either *mult* VI VI EXT or *mult* VI EXT VI to *mult* VI EXT EXT was induction. This effect was consistent throughout the experiment for Pigeons 128 and 139. Pigeon 141 deviated from this pattern once, on the sixth condition. Over successive conditions, this pigeon also demonstrated a tendency toward increased constant-key responding, ac-

Table 2

Responses per minute (average last five days) on each key in each component of the three-component multiple schedule of Experiment 2.

Condition			*# Sessions*	*Bird #*
1	*2*	*3*		
1. VI 1-min	VI 1-min	EXT	18	128
				139
				141
2. VI 1-min	EXT	EXT	10	128
				139
				141
3. VI 1-min	EXT	VI 1-min	11	128
				139
				141
4. VI 1-min	EXT	EXT	10	128
				139
				141
5. VI 1-min	VI 1-min	EXT	12	128
				139
				141
6. VI 1-min	EXT	EXT	10	128
				139
				141
7. VI 1-min	EXT	VI 1-min	10	128
				139
				141
8. VI 1-min	EXT	EXT	9	128
				139
				141

Table 2 (continued)

Resp/min (Average of last five sessions)								
Operant Key			*Stimulus Key*			*Total*		
1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
37.9	33.9	8.5	0.5	8.7	0.3	38.4	42.6	8.8
50.4	62.3	5.0	17.0	23.3	0.2	67.4	85.6	5.2
49.1	54.2	15.0	68.5	65.0	1.4	117.6	119.2	16.4
32.1	5.3	0.6	0.2	0.3	0.2	32.3	5.6	0.8
38.0	3.2	3.5	35.0	0.5	0.1	73.0	3.7	3.6
46.8	16.2	40.9	94.4	8.1	2.4	141.2	24.3	43.3
41.1	13.4	39.7	6.8	0.5	2.5	47.9	13.9	42.2
51.6	10.5	50.5	20.2	0.2	0.1	71.8	10.7	50.6
69.0	25.8	78.2	59.1	0.6	26.8	128.1	26.4	105.0
37.3	0.5	5.1	27.3	0.2	0.3	64.6	0.7	5.4
41.1	1.3	2.9	36.3	0.2	0.2	77.4	1.5	3.1
61.2	7.6	57.5	79.8	0.3	3.4	141.0	7.9	60.9
50.1	36.9	5.1	4.4	52.5	0.2	54.5	89.4	5.3
41.1	35.4	7.6	26.9	43.5	0.3	68.0	78.9	7.9
73.6	73.4	29.1	37.8	42.5	0.2	111.4	115.9	29.3
39.2	2.1	2.9	55.1	0.3	0.0	94.3	2.4	2.9
38.1	1.6	11.2	40.1	0.7	0.7	78.2	2.3	11.9
91.3	3.8	52.0	29.1	0.9	0.3	120.4	4.7	52.3
44.2	5.0	55.0	52.3	0.3	7.2	96.5	5.3	62.2
43.0	5.6	55.4	32.7	0.3	1.5	75.7	5.9	56.9
94.0	37.6	92.2	11.7	0.1	28.5	105.7	37.7	120.7
37.5	0.4	5.3	63.9	0.2	0.4	101.4	0.6	5.7
34.9	1.6	11.4	48.6	0.2	0.5	83.5	1.8	11.9
85.6	3.6	54.6	20.7	0.0	0.8	106.3	3.6	55.4

companied by a decrease in stimulus-key responding.

The general pattern of stimulus-key responding was that of contrast. This pattern is obscured somewhat in Pigeon 128 because of the late development of stimulus-key responding. The changing rates of stimulus-key responding over the eight conditions for Pigeons 128 and 139 was not accompanied by a change in constant-key responding.

When component- and constant-key response rates are added, the result is similar to the positive contrast typical of single-key multiple schedules. In the present experiment, this contrast was achieved by the combined effect of induction on the constant key and contrast on the stimulus key, with the stimulus-key contrast being larger than the constant-key induction.

GENERAL DISCUSSION

The results of the present experiments are in general agreement with the following conclusions:

(1) In addition to an operant class of key pecks, there is a class of pecks elicited by and ordinarily directed to a stimulus associated with a high rate of reinforcement when that stimulus alternates with an extinction stimulus.

(2) The two-key procedure, which displaces the stimulus for elicited pecks to a second key while retaining the response-reinforcer contingency on the first key, is reasonably successful in dissociating the two classes. In the case of the first experiment, one bird failed to respond to the stimulus key and displayed some contrast on the constant key. In the second experiment, one bird decreased its responding to the stimulus key over sessions, while increasing its constant-key responding. These exceptions suggest that not all of the elicited pecks were directed to the stimulus key. This partial failure to maintain complete control of elicited pecking is consistent with the speculation of Rachlin (1973), that variables other than the stimuli that occasion the elicited responses may come to control the direction of those responses. Schwartz (1973) confirmed that this can occur with an experimental procedure in which elicited responses were directed to the response key but elicited by a tone.

(3) Schedule changes that typically produce positive behavioral contrast effects in a single-

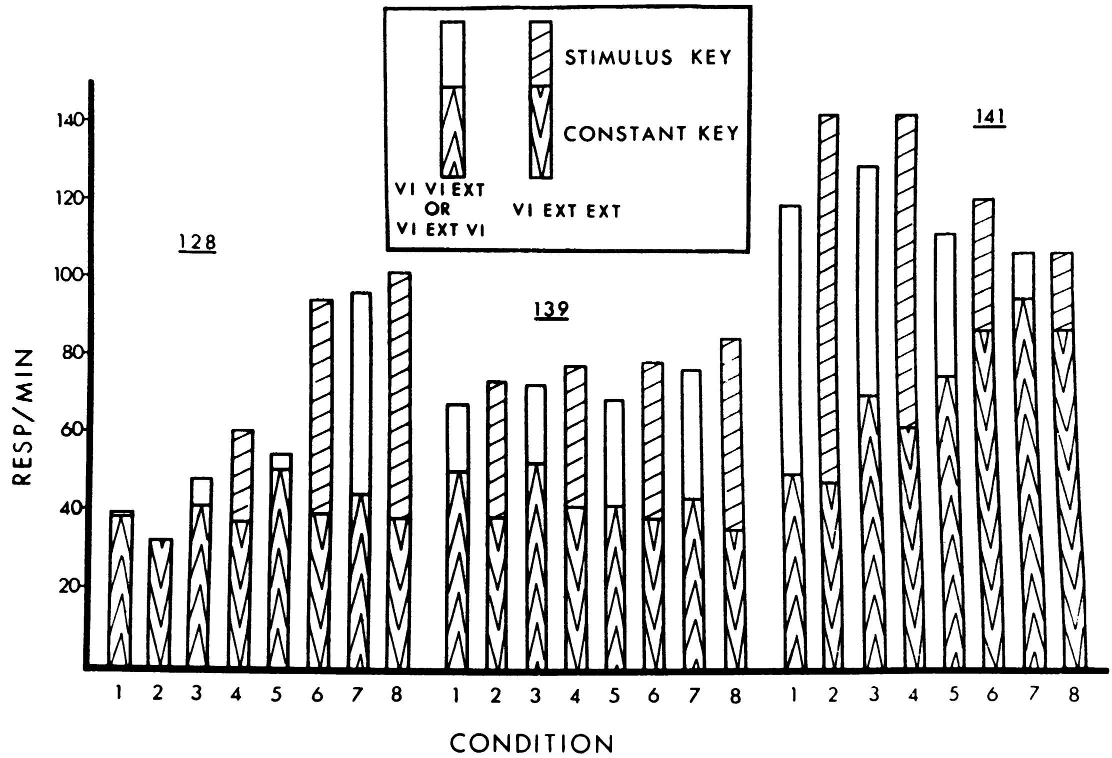

Fig. 2. Rates of responding (average of last five sessions) in the first component of the three-component multiple schedule of Experiment 2. Each bar shows total responding in that component, segmented into pecks to the constant key and to the stimulus key.

key procedure produce induction on the constant key and contrast on the stimulus key in a two-key procedure. This is the case even when pecks are displaced to the second key before schedule changes intended to produce contrast are introduced.

A note on the rationale of the two-key procedure is in order. The attempt to separate operant and elicited pecks by displacing the component stimuli to a second key is an application of the more general technique of "topographical tagging" introduced by Catania (1971, 1973). According to this procedure, two response classes that occur to the same key, but which are controlled by different variables, can be separated without loss to the total output by separating the controlling variables. This assumption of output constancy received support in Catania's experiments, in which different delays and rates of reinforcement were investigated. In Experiment 1b, this constancy assumption was questioned. The two-key situation is obviously sufficiently different from the single-key situation to introduce additional confounding variables. It is likely that the displacement of the component stimuli away from the operant key changes the quality of the discrimination. There is evidence of incomplete discrimination on the constant key in the present experiments. The second key also may make the situation more complicated because of the introduction of a third response class, namely, changeover responses. A third possibility concerns the procedure of alternating sessions of the single-key with sessions of the two-key procedure. Would the same results be obtained if the two procedures were alternated frequently within sessions? It remains to be seen if a procedure could be designed that would result in output constancy.

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