

*BEHAVIORAL CONTRAST IN THE PIGEON: A STUDY OF THE DURATION OF KEY PECKING MAINTAINED ON MULTIPLE SCHEDULES OF REINFORCEMENT*<sup>1</sup>

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Pecks on an operant key were reinforced on either multiple variable-interval variable-interval or multiple variable-interval extinction schedules of reinforcement. The stimuli that signalled the multiple-schedule components were located on a second key (signal key), and a changeover delay prevented reinforcement of signal key-peck—operant key-peck sequences. No behavioral contrast was observed on the operant key, and appreciable responding to the signal key occurred during the variable-interval component of the multiple variable-interval extinction procedure. Peck durations on the signal key were markedly shorter than peck durations on the operant key. Moreover, most responses on the signal key occurred just after the multiple-schedule components changed. These data support an account of behavioral contrast in terms of the summation of pecks that are separately controlled by stimulus-reinforcer and response-reinforcer dependencies, and suggest that the stimulus-reinforcer dependency is responsible primarily for local contrast. In addition, the data suggest that pecks that are controlled by these two dependencies may belong to topographically different classes.

*Key words:* behavioral contrast, local contrast, stimulus-reinforcer dependency, elicited pecking, response duration, multiple schedules, signal key, key peck, pigeons

In recent years, substantial evidence has accumulated that Pavlovian, stimulus-reinforcer dependencies can generate and maintain key pecking in pigeons. The initial demonstration was made by Brown and Jenkins (1968). They showed that if a response key is periodically illuminated and followed by food presentation, naive pigeons come to peck reliably at the response key, typically within 50 to 100 trials (autoshaping). Gamzu and Williams (1971, 1973) extended these findings by showing that key pecking occurred if and only if response-key illumination was a differential predictor of food. If food presentation was as likely in the absence of the keylight as in its presence, key pecking was not established, and if already established by some other procedure, was not maintained. These findings and numerous others (see Hearst and Jenkins, 1974; Schwartz and Gamzu, *in press*, for reviews) have led investigators to propose that key pecking can be generated via mechanisms of Pavlovian condi-

tioning, much akin to conditioned salivation in the dog (*e.g.*, Jenkins and Moore, 1973; Morse, 1973).

The rather compelling evidence for Pavlovian control of key pecking leads one to the problem of ascertaining how pecks controlled by stimulus-reinforcer dependencies and pecks controlled by response-reinforcer dependencies are related. Schwartz and Williams (1972*b*) obtained evidence that suggested two different kinds of key pecks, distinguishable by their duration. One type of peck, of short duration, appeared to be sensitive to stimulus-reinforcer dependencies and insensitive to response-reinforcer dependencies. A second type of peck, of long duration, appeared sensitive to response-reinforcer dependencies. The problem with the Schwartz and Williams study was that the observed duration differences were not clear-cut enough to provide unequivocal evidence that they represented two different kinds of key pecks. Indeed, there is some unpublished evidence (Warren, cited by Moore, 1973) that contradicts the Schwartz and Williams study. Thus, one aim of the present study was to collect additional information on peck duration as a function of the type of contingency (Pavlovian or operant) that controlled key pecking.

Aside from the issue of whether Pavlovian and operant contingencies actually control dif-

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ferent types of key pecks, there is a question as to how the two types of contingency interact to control pecking when both are present in the same experimental situation. Gamzu and Schwartz (1973) suggested that if a procedure includes a differential stimulus-reinforcer dependency, that dependency will generate and maintain pecking, even if a response-reinforcer dependency is also controlling pecking. In support of this view, Gamzu and Schwartz suggested that the widely reported phenomenon of positive behavioral contrast (Reynolds, 1961) could be interpreted as an instance of the interaction of response-reinforcer and stimulus-reinforcer dependencies in the control of pecking. Their account of positive behavioral contrast has received substantial empirical support (Hemmes, 1973; Keller, 1974; Rachlin, 1973; Redford and Perkins, 1974; Schwartz, 1974, 1975; Westbrook, 1973; see Schwartz and Gamzu, *in press*, for a review).

The present study was designed to provide a further assessment of this account of contrast (called the "additivity theory" by Schwartz and Gamzu, *in press*), in conjunction with an investigation of response duration. Suppose that a pigeon is exposed to a series of multiple-schedule procedures that ordinarily result in positive behavioral contrast. Unlike standard multiple-schedule procedures, in which the stimuli that signal the components of the multiple schedule are located on the response key, in this procedure the response key is always illuminated by the same stimulus and the multiple-schedule components are signalled on a second key. Keller (1974) employed this procedure to separate spatially stimulus-reinforcer and response-reinforcer dependencies. He found that during *mult VI EXT*, pecks on the operant key did not increase in frequency, *i.e.*, there was no positive contrast. However, substantial rates of responding occurred on the signal key. Operant-key and signal-key responses, if summed, synthesized positive contrast, a strong confirmation of the additivity theory of contrast. Schwartz (1975) has obtained similar findings. Suppose that one recorded response durations in procedures of this type. On the basis of the evidence reviewed above, one would expect pecks on the operant key, controlled by a response-reinforcer dependency, to be of long duration, while pecks on the signal key, controlled by a stimulus-reinforcer dependency, would be of short dura-

tion. Such a result would support both the additivity theory of contrast and the view that the two types of contingencies control different types of responses.

## METHOD

### *Subjects*

Four male Silver King pigeons were deprived to 80% of free-feeding weights. They had previously been exposed to positive and negative automaintenance procedures (*e.g.*, Schwartz and Williams, 1972a), and to multiple schedules of reinforcement.

### *Apparatus*

The experimental chamber was 27.5 cm high by 32.5 cm wide by 29.0 cm deep. Three of the walls were made of galvanized steel. The front wall was stainless steel. Centered on this wall, 5.5 cm from the floor, was a food magazine that permitted 4-sec access to mixed grain when operated. Three response keys were located 21 cm above the floor, 6.5 cm apart, center-to-center, though only the two side keys were used. They were Gerbrands normally closed keys requiring a force of 0.1 N to operate. A houselight, illuminated at all times except during food delivery, was located above the center key, 26.25 cm from the floor of the chamber. Scheduling of experimental events, data collection, and analysis were accomplished with a Digital Equipment Corporation PDP 8/E digital computer using SKED software provided by State Systems, Inc., of Kalamazoo, Michigan. In recording response durations, all interresponse times shorter than 10 msec were gated out to allow for contact bounce, dust, *etc.*; however, a response duration as short as 5 msec could be recorded.

### *Procedure*

The pigeons were exposed to a *mult VI 2-min VI 2-min* schedule (10 sessions), followed by a *mult VI 2-min EXT* schedule (19 sessions), and then were returned to the *mult VI 2-min VI 2-min* schedule (21 sessions). In all procedures, multiple-schedule components were signalled by red or green illumination of one side key (signal key), while reinforcement depended on pecks at the other side key (operant key), which was illuminated by a white vertical line. For two pigeons, the left key was the operant key; for the other two, the right key was the operant. Throughout the experi-

ment, a 2-sec changeover delay (COD) was operative: no operant-key response that occurred less than 2 sec after a signal-key response was reinforced. The COD was included in this procedure because the results of a pilot experiment that immediately preceded the present one suggested that signal-key pecks might be adventitiously reinforced as members of signal key-peck-operant-key peck chains. The pilot experiment was virtually identical to the present one, except for the absence of the COD. No differences in the duration of signal-key and operant-key responses were observed. In addition, some pigeons responded as frequently on the signal key as on the operant key. This led to the hypothesis that an adventitious response-reinforcer contingency was contributing to the maintenance of (long duration) signal-key responses. Thus, the COD was instituted to minimize effects of adventitious reinforcement.<sup>2</sup>

Each daily session consisted of sixty 2-min components with the two schedules alternated regularly. Data were collected separately for the first 10 sec and remaining 110 sec of each component. This was done to allow assessment of local positive-contrast effects (*e.g.*, Malone and Staddon, 1973; Nevin and Shettleworth, 1966), which are increases in responding that occur just after transition from one component schedule to the other and gradually dissipate during the component.

## RESULTS

Session-to-session response rates on the operant key in both components of the multiple

<sup>2</sup>Data from this experiment are available on request from Alan Silberberg, Department of Psychology, The American University, Washington, D.C. 20016.

schedule and on the signal key during the unchanged VI 2-min component are presented in Figure 1. Only Pigeon 11 showed a pronounced contrast effect during the *mult* VI 2-min EXT procedure. However, that pigeon's response rate remained high for 14 sessions of the *mult* VI 2-min VI 2-min procedure that followed the *mult* VI 2-min EXT. If stringent criteria for demonstrating behavioral contrast are applied, which require a return to baseline responding when the multiple schedule is returned to VI 2-min VI 2-min, the contrast effect shown by Pigeon 11 is equivocal.

Responding on the signal key was substantially greater during *mult* VI 2-min EXT than during *mult* VI 2-min VI 2-min. This can be seen more clearly in Table 1, which presents absolute rates of responding across the last five sessions of each procedure for each pigeon. Signal-key responding is presented in parentheses. Though signal-key rates differ between *mult* VI VI and *mult* VI EXT, they are substantially lower overall than previous research has indicated (Keller, 1974; Schwartz, 1975). Thus, the COD seems to have reduced signal-key responding. This suggests that some signal-key responding observed in previous research (including the pilot experiment described above) has in fact been maintained by an adventitious response-reinforcer contingency.

Figure 2 presents relative-frequency distributions of response duration on the operant and signal keys during the unchanged VI 2-min component over the last five sessions of each procedure. The number of responses represented is indicated in each panel, as is the median duration. For Pigeons 11 and 41, distributions of duration for signal-key pecks during the *mult* VI 2-min VI 2-min procedures are not presented because there were fewer than 20 total signal-key pecks on these procedures.

Table 1

Responses per minute in each multiple-schedule component averaged across the last five sessions of each procedure.

Procedure	P11		P21		P31		P41	
	S1	S2	S1	S2	S1	S2	S1	S2
VI 2-min VI 2-min (Signal Key)	62.5 (0.0)	59.7 (0.0)	26.8 (0.2)	25.6 (0.2)	41.4 (0.5)	40.0 (0.2)	44.6 (0.0)	43.0 (0.0)
VI 2-min EXT (Signal Key)	77.0 (0.3)	11.5 (0.0)	29.7 (1.1)	5.6 (0.1)	45.1 (0.7)	4.3 (0.1)	36.7 (0.5)	9.3 (0.0)
VI 2-min VI 2-min (Signal Key)	44.1 (0.0)	37.6 (0.0)	31.8 (0.3)	31.8 (0.2)	22.7 (0.2)	19.5 (0.0)	45.2 (0.0)	45.2 (0.0)

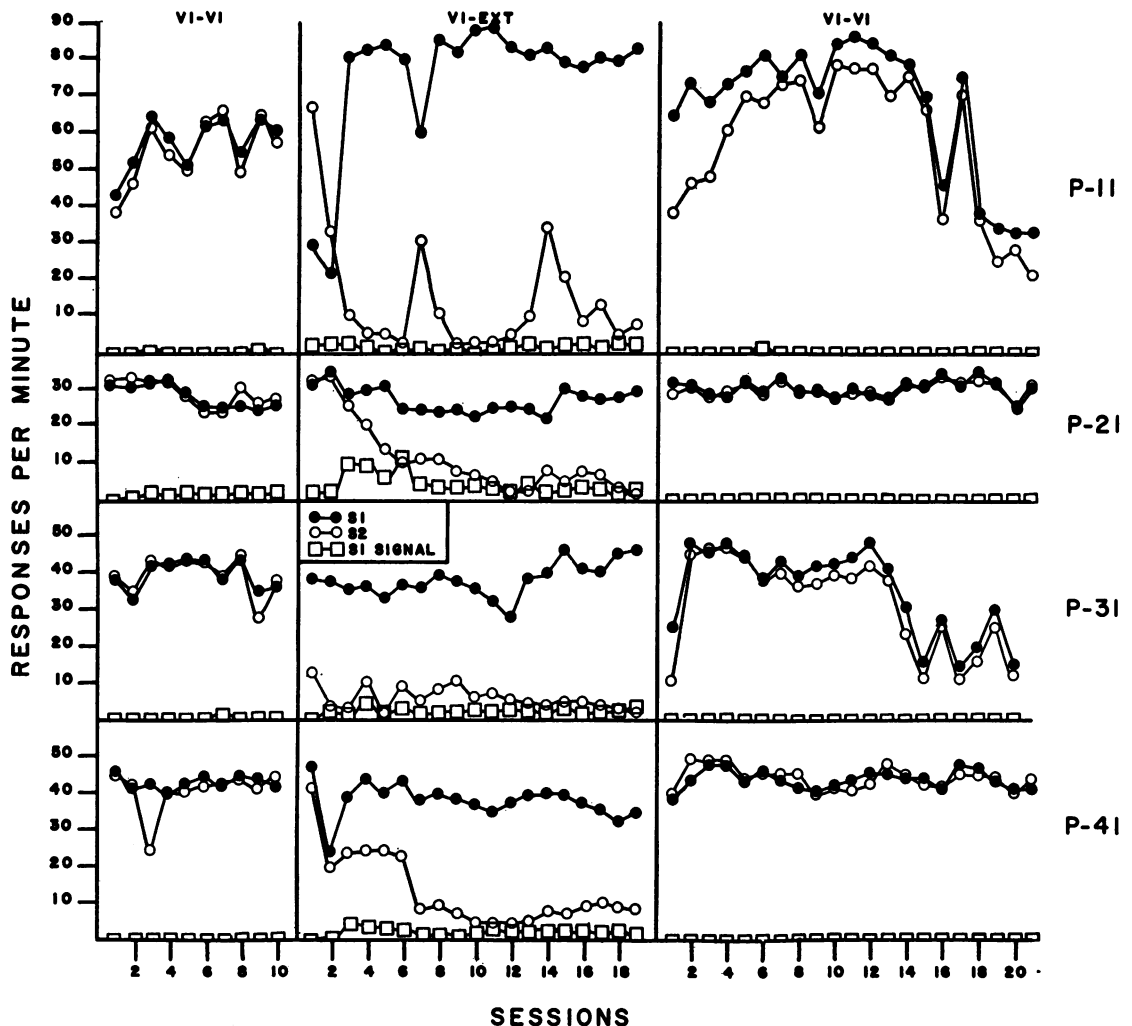


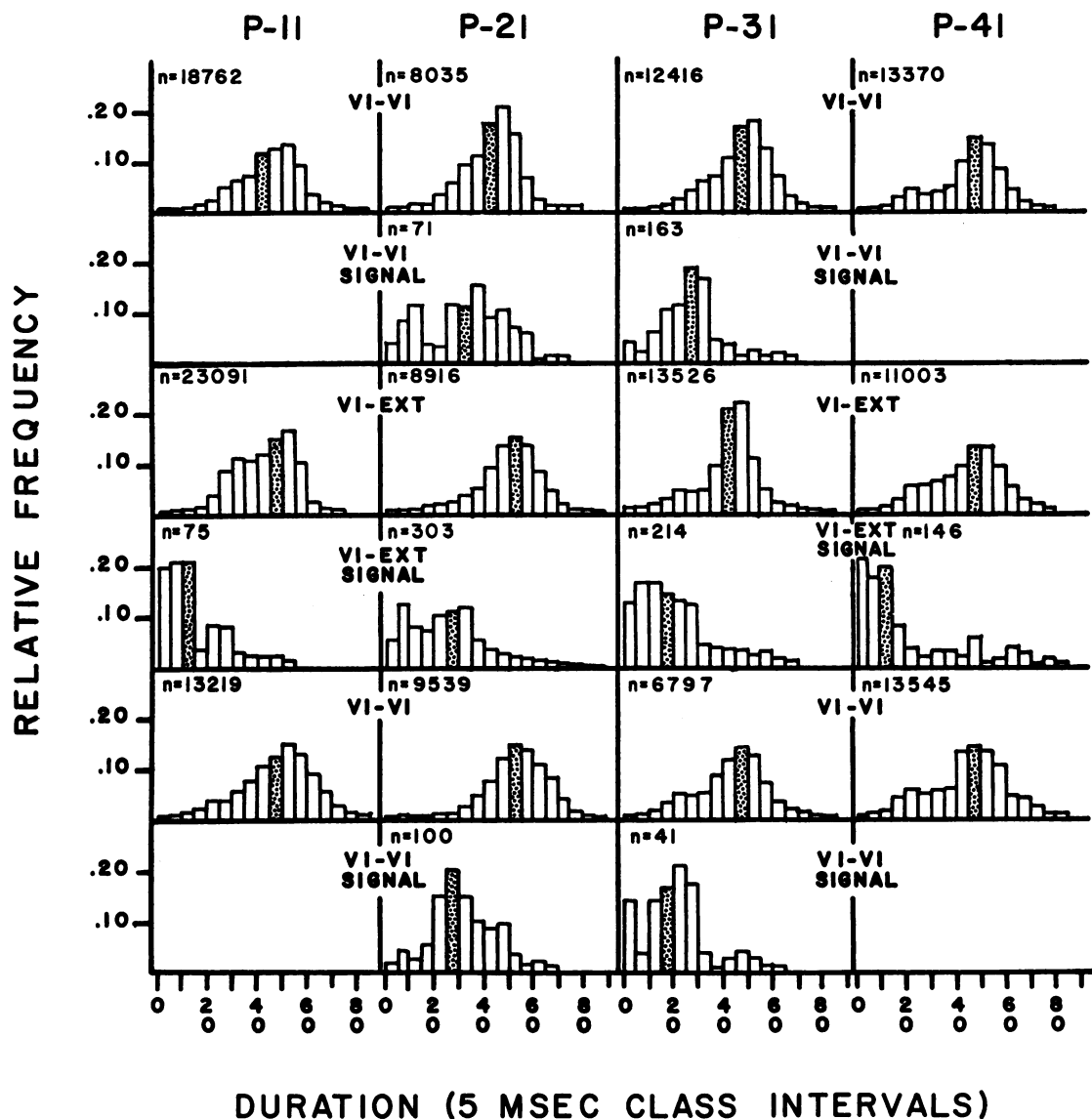
Fig. 1. Session-to-session response rates in both components of the multiple-schedule procedures. Filled circles represent response rates in the constant VI 2-min component and open circles represent response rates in the other component, which was either VI 2-min or EXT. The open squares represent response rates on the signal key when it signalled the constant VI 2-min schedule. The different multiple-schedule procedures are identified at the top of each panel.

The median duration on the operant key was between 45 and 55 msec on all procedures. However, on the signal key, the median duration was 15 msec for Pigeons 11 and 41, 20 msec for Pigeon 31, and 30 msec for Pigeon 21 during the *mult* VI 2-min EXT procedure. It thus appears that operant and elicited pecks can be distinguished on the basis of duration.

It might be argued that short durations occur when pigeons peck the key at low rates, as with the signal-key data in this experiment. Evidence against this view can be found in the EXT responding of Pigeons 21 and 31. By the end of the *mult* VI 2-min EXT procedure,

these pigeons were pecking the operant key during EXT at very low rates. Nevertheless, median duration was 55 msec for Pigeon 21 and 50 msec for Pigeon 31.

Table 2 presents the proportion of total responses emitted across the last five sessions of each procedure that occurred in the first 10 sec of each component. If there were no within-component differences in response rate, one would expect 0.085 of the total pecks emitted to occur in the first 10 sec of the component. During *mult* VI 2-min VI 2-min procedures, the proportions of operant-key responses during the first 10 sec of each component ranged



### DURATION (5 MSEC CLASS INTERVALS)

Fig. 2. Relative frequency distributions of peck duration, in 5-msec class intervals, during the constant VI 2-min component of each multiple-schedule procedure. Distributions were taken over the last five sessions of each procedure, and are presented separately for operant-key and signal-key responses. The number of responses represented by each distribution is indicated in each panel, and the median of each distribution is indicated by the stippled bar.

from 0.08 to 0.10, *i.e.*, there was no evidence of local differences in response rate. Signal-key responding on these procedures, when it occurred at all, was much more variable. The proportions ranged from 0.03 to 0.26. This variability was probably due to the small number of responses in each cell. Indeed, some cells of Table 2 have no entry because fewer than 10 total signal-key responses occurred over the five sessions. Of interest are the proportions ob-

served during *mult* VI 2-min EXT. A local positive-contrast effect would be revealed in proportions greater than 0.085. On the operant key, there were only three proportions greater than 0.09. Pigeon 31 emitted 0.12 of its responses during the VI 2-min component in the first 10 sec, evidence for local contrast. The other two instances, for Pigeon 21 and Pigeon 41, occurred during the EXT component. They are thus not evidence of local contrast.

Table 2

Proportion of total responses emitted during the first 10 sec of each component over the last five sessions of each procedure.

Procedure	P11		P21		P31		P41	
	S1	S2	S1	S2	S1	S2	S1	S2
VI 2-min VI 2-min	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.09
VI 2-min VI 2-min (Signal Key)	—	—	0.04	0.11	0.26	0.07	—	—
VI 2-min EXT	0.06	0.08	0.09	0.12	0.12	0.08	0.09	0.16
VI 2-min EXT (Signal Key)	0.59	—	0.32	0.03	0.77	0.00	0.14	—
VI 2-min VI 2-min	0.08	0.10	0.08	0.08	0.08	0.10	0.08	0.08
VI 2-min VI 2-min (Signal Key)	—	—	0.03	0.06	0.19	—	—	—

On the other hand, the proportion of responses on the *signal key* emitted during the first 10 sec was striking. Pigeons 11, 21, 31, and 41 emitted 0.59, 0.32, 0.77, and 0.14 respectively of their total signal-key pecks during the first 10 sec of the VI 2-min component. Thus, there is strong evidence of a local contrast effect on signal-key pecking.

## DISCUSSION

The present results may be summarized as follows:

1. Behavioral contrast was not observed when multiple-schedule components were signaled on a separate key.

2. Pecks were directed at the signal for the VI 2-min component of a *mult* VI 2-min EXT schedule, though at a lower rate than previous studies have observed.

3. The duration of responses on the signal key was substantially shorter than duration of responses on the operant key. The duration difference could not be attributed to the response-rate difference on the two keys.

4. Most signal-key responses occurred just after a change from the EXT component to the VI component. This temporal pattern was not observed for operant-key responses.

These data have two major implications for the additivity theory of contrast (Gamzu and Schwartz, 1973; Rachlin, 1973; Schwartz and Gamzu, *in press*). First, signal-key responding was sufficiently infrequent that summation of signal-key and operant-key responses would not yield a positive contrast effect. In two previous studies (Keller, 1974; Schwartz, 1975), signal-key responding was substantial enough to synthesize positive contrast if summed with oper-

ant-key responding. The major difference between this study and the previous ones was the presence of a COD in the present study. The COD was designed to prevent possible adventitious reinforcement of signal-key pecks that were followed closely in time by operant-key pecks and food. It seems reasonable to conclude that the COD was responsible for the difference between this study and the previous ones. This implies, however, that adventitious reinforcement of signal-key pecks exerted control over these pecks in the Keller (1974) and Schwartz (1975) studies, *i.e.*, that spatial separation of Pavlovian and operant contingencies did not necessarily eliminate their interaction. If this is the case, then the additivity theory of contrast may not be a sufficient account of the phenomenon. It may also be necessary to argue that pecks generated by the Pavlovian stimulus-reinforcer dependency are subsequently reinforced by the operant response-reinforcer dependency.

The second major point raised by these data is the possibility that the additivity theory of contrast accounts primarily for local contrast, rather than overall contrast. There are numerous demonstrations of local positive contrast with pigeons (*e.g.*, Boneau and Axelrod, 1962; Malone and Staddon, 1973; Nevin and Shettleworth, 1966). These studies have shown that immediately after transition from a multiple-schedule component with less frequent reinforcement to one with more frequent reinforcement, there is a temporary increase in responding, which gradually returns to baseline level as the component continues. While local contrast effects may contribute substantially to overall contrast, the two are not identical. Boneau and Axelrod (1962) for example,

reported sustained overall contrast effects for many sessions after local contrast had ceased (see Schwartz and Gamzu, *in press*, for a review). One might expect, however, that the shorter the multiple-schedule components are, the more that local contrast will contribute to overall contrast. In the present experiment, components were 2 min long, yet the bulk of signal-key responding occurred in the first 10 sec. Rachlin (1973) also provided evidence that suggests that the additivity theory accounts primarily for local contrast effects. Pigeons were exposed to a mult VI 2-min VI 2-min schedule. In one of the components, free reinforcements were delivered at variable intervals averaging 15 sec. The additivity theory would predict that response rate in the component with free reinforcement would be higher than response rate in the other component, owing to a differential stimulus-reinforcer relation. Rachlin found this to be true when components were 8 sec long, but not when they were 8 min long. In the 8-min components, responding at the onset of the component containing free reinforcement was indeed higher than in the other component. However, rate decreased over the course of the component (local contrast), so that if rate was averaged across the entire component, there was no difference in responding maintained by the two different schedules.

Another feature of the present data that warrants discussion is the duration difference between responses on operant and signal keys. With a COD in the procedure, there are impressive differences in duration on the two keys. Pilot research showed, however, that there was no duration difference without a COD. We argued above that this is because an adventitious response-reinforcer relation reinforces short-duration pecks on the signal key, with the result that long-duration pecks also occur. This raises a rather mysterious question, which was also raised, but not answered, in an earlier study of response duration (Schwartz and Williams, 1972b).

Where do these long-duration pecks come from? Long-duration pecks have not themselves been reinforced, according to the present argument. First, short-duration pecks are generated by a stimulus-reinforcer dependency. Second, these pecks, if followed by reinforcement give rise to a new population of pecks, which will subsequently be sensitive to their consequences. The problem is essentially a spe-

cific restatement of one of the more long-standing and difficult questions in psychology: by what mechanism does voluntary behavior (defined as behavior that is sensitive to its consequences) emerge from the collection of reflexes that characterize the infantile organism? In a recent discussion of this problem, Kimble and Perlmutter (1970) suggested that voluntary behavior may depend upon a reflexive substrate and suggested a process of "anaclitic reinforcement", whereby operant behavior may emerge from its reflexive origins. Their account is consistent with the data and analysis offered here. The study of key pecking in the pigeon may turn out to be an ideal preparation for the study of the origins of voluntary behavior.

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