PREFERENCE FOR INTERMITTENT REINFORCEMENT¹

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Two experiments were conducted demonstrating that under certain conditions pigeons may peck at a higher rate on a key that produces intermittent reinforcement following a delay than on one that always produces reinforcement following the same delay duration. In both experiments, concurrent chain schedules were employed. In Experiment I, a single peck on one key led to a white light and a delay of 15 sec, which always terminated with food. A peck on the other key led to its illumination by one of two colored lights and a delay period of 15 sec. The delay was followed by either food presentation or timeout, either one lasting 3 sec. In a control group, the lights on this key were not correlated with food or timeout. Under the correlated stimuli, birds more often pecked the key leading to intermittent reinforcement, whereas with uncorrelated stimuli they pecked the key leading to the white light and 100% reinforcement. In Experiment II, concurrent variable-interval schedules were employed in the first link. The results showed generally that the relative rate was higher on the key leading to intermittent reinforcement when the stimuli were correlated with reinforcement and timeout than on the key leading to 100% reinforcement. There was some indication that this performance was affected by (1) the duration of the delay, (2) the percentage of reinforcement on the key yielding the higher percentage of reinforcement (the key with the white light), and (3) prior experimental conditions.

Using a modified chain schedule procedure, Wilton and Clements (1971a) showed that pigeons may peck at a higher rate in the initial component when the stimuli for the terminal component are correlated with a relatively low density of reinforcement than when the stimuli for the terminal component are correlated with a relatively high density of reinforcement. These findings are contrary to the usual findings obtained with chained schedules, which show that the response rate in the initial component increases as the frequency of reinforcement in the terminal component increases (see Kelleher, 1966).

In their experiment, Wilton and Clements compared three conditions. In all conditions, pigeons responded on a fixed-interval schedule in the initial link. Two stimuli are correlated with the terminal link, which was a fixed duration with free reinforcement or timeout at the end. In one condition, food delivery was

correlated with only one of the two stimuli in the terminal link; the other stimulus was followed by a short timeout. In another condition, food was delivered at the end of half of the terminal links, but neither stimulus was reliably correlated with its delivery. In the third condition, each terminal link, regardless of the stimulus, terminated with food delivery. The response rate in the initial component was highest in the first of these conditions, without much difference between the last two conditions. A study by Kendall (1972) replicated these findings with terminal links of two different durations and reinforcement in each. Response rates were higher in the initial component followed by one long and one short terminal component than in the component followed by two short terminal components. This effect disappeared, however, when the two stimuli for the terminal components were no longer reliably correlated with the duration of the terminal components.

Wilton and Clements (1971a) and Wilton (1972) interpreted the findings of the Wilton and Clements experiments in terms of an information hypothesis. The information hy-

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pothesis of observing responses has been elaborated by Wilton (1972) and extended to the partial reinforcement acquisition phenomenon. One finding contrary to the hypothesis is that, although rats may run faster in alleys when they receive intermittent reinforcement than when they receive 100% reinforcement (Wagner, 1961), they do not choose the arm of a T-maze that leads to intermittent reinforcement over one leading to 100% reinforcement (Spear and Spitzner, 1967). Usually, in this situation the information as to whether food is available comes at a delay after the response of entering one arm. Perhaps if discriminative stimuli were available immediately following a turn, the animals would choose the intermittent side over the side that provides 100% reinforcement. The present experiment was designed to test this hypothesis with pigeons as the subjects.

EXPERIMENT 1: CONCURRENT FR 1 CHAIN SCHEDULES

METHOD

Subjects

Eight experimentally naive female White Carneaux pigeons, 3 to 5 yr old, served.

Apparatus

A commercial (Lehigh Valley Electronics) pigeon chamber contained two response keys, each key requiring a force of about 15 g (0.15N) to operate. The lights behind the key were ESB type 28-V 0.84-W bulbs housed in ceramic containers. Red and green colored caps supplied with the chamber were used to provide red and green keylights. The white light was provided by an uncovered bulb. Electromechanical scheduling and recording equipment was used to arrange and record the experimental events. The scheduling equipment was located in a separate room from the pigeon chamber. White masking noise was provided in the room in which the pigeon chamber was placed.

Procedure

The pigeons had been housed in the animal colony for about three months before this experiment. When the experiment was begun, the birds were arbitrarily divided into two

groups. The birds were food-deprived until they reached about 80% of their free-feeding weight and were maintained at this level throughout the experiment.

The pigeons were trained by reinforcement of successive approximations to peck at one of the response keys. Both keys at this time were dark. The key to which they were trained was then covered by a piece of tape and they were trained to peck the other key. During shaping and subsequent experimentation, the grain hopper was presented for 4 sec with the houselight unlit. The procedure for both experiments was a concurrent chains procedure diagrammed in Figure 1. In Experiment I, the reinforcement schedule in the initial component was a fixed-ratio of one response (FR 1). In the initial link, both keys were dark. A peck on one of the keys produced a white light and a delay interval that was followed by presentation of the grain hopper. For convenience, this key will be called the *high-density key*, since each peck on it resulted in grain following the delay. A peck on the other key produced one of two lights on the key, either red or green. The grain hopper was presented after half of the delay intervals for this key. A 4-sec blackout was presented after the other half. This key will be called the *low-density key*. Over a number of sessions, varying from six to 12 for different birds, the delay intervals were all simultaneously lengthened until delays of 15 sec had been attained. Also during this phase of training, one of the keys was covered during each session so that a bird had to obtain all reinforcers during a session by pecking only one key. If the low-density key was operative during one session, the high-density key would be operative during the next session. The number of reinforcers obtained on each key was equated for each bird during this phase, but the number of reinforcers was not equated from bird to bird due to the differing numbers of sessions given to individual birds. Equating reinforcers resulted in twice as many pecks being made to the low-density key and twice as many delay intervals on this key. Each peck during the last 2 sec of a delay interval postponed the termination of the delay stimulus by 2 sec. Immediately following reinforcement or timeout, the bird was free to respond again and initiate a new delay.

Fig. 1. Diagrams of the concurrent chains procedure. The first box represents the state of the keys in the initial link (both dark). The box on the upper right represents the conditions upon entering the terminal link on that key. The key turned white, there was a delay, and food was delivered. The other key was inactive during the delay period. The lower box on the right represents the consequences of entering the terminal link on that key. The key turned either green or red, there was a delay, and either food or timeout occurred. The other key was inactive during the delay. Entering the terminal components was accomplished on either concurrent FR 1 schedules (Experiment 1) or concurrent VI 20-sec schedules (Experiment 11).

During this initial training and subsequent experimentation there were two groups of birds. For one group, pecking the low-density key led to stimuli (red and green keylights) that were correlated with the subsequent arrival of grain or timeout. If the green light followed a peck, grain was delivered; if the red light followed a peck, the delay terminated in timeout. For the other group, the red and green lights on the low-density key were uncorrelated with subsequent grain or timeout. For both groups, pecking the high-density key always led to the white light which, in turn, was always followed by grain delivery. Two subjects in each group were trained originally with the left key as the high-density key and the right key as the low-density key, and two were trained with the opposite arrangement.

Following the preliminary training described above, the subjects in the group with the correlated stimuli on the low-density key (correlated group) were given 15 sessions of exposure to the concurrent FR 1 schedule. Pecking a key had exactly the same consequences as in preliminary training, except that both were available before a delay in-

terval. Once one of the keys had been pecked, the other key became inoperative. The group with the uncorrelated stimuli (uncorrelated group) on the low-density key was given 10 sessions of exposure to the concurrent schedule. Following these concurrent chains sessions, the function of each key was reversed for the birds in both groups for 15 sessions. Thus, the low-density key became the high-density key and *vice versa*. A session lasted until 40 grain reinforcers had been obtained.

After the above procedures were completed, the subjects in the uncorrelated group were given four sessions of forced trials to the low-density key, with the delay stimuli correlated with reinforcement and timeout. The consequences of pecking the low-density key were exactly as described for the correlated group. Following these four sessions, the birds were then given 10 concurrent chains sessions with the high- and low-density keys both available.

RESULTS

The results for the correlated group are presented in Figure 2. The data plotted are the per cent of pecks on the low-density side during the initial links of the concurrent chains sessions. Data for each bird are presented plotted across sessions. All four subjects eventually pecked predominantly on the low-density key, with averages of about 80% to 100%. When the consequences associated with the keys were reversed, three of the birds showed an increase in pecks on the low-density side, although at the end of 15 sessions the per cent of pecks on that side was not as great as at the end of the previous 15 sessions. The data for Bird 2 are different from the others, showing an increase in pecks on the low-density key followed by a decrease after the switch.

Figure 3 shows that the uncorrelated group had a fairly rapid decline in pecking the low-density key, and at the end of the first 10 sessions, the number of responses to that key was quite low. When the consequences associated with the keys were reversed, all of the birds began pecking frequently on the new high-density side in the first session, followed by an increase in pecks on the high-density key. There was some variability during the subsequent sessions, with some animals pecking on the low-density key (old high-density key) on occasion, but by the end of the 15 sessions,

Fig. 2. Per cent choices for the low-density side for each subject in the correlated group. The data are plotted across sessions. The first panel shows the results in the original training and the second panel shows the results following the reversal of the functions of the keys.

a clearly higher proportion of pecks occurred on the high-density key.

Figure 4 shows that the birds originally in the uncorrelated group pecked predominantly on the low-density key after exposure to the correlated stimuli on that key. From the outset of the concurrent chains sessions, three of the birds pecked more on the low-density side and continued to do so throughout the 10 sessions. One of the birds, Bird 8, showed an increasing tendency to peck on the high-density key during these sessions.

EXPERIMENT II: CONCURRENT VARIABLE-INTERVAL SCHEDULES

One difficulty with concurrent FR 1 chains is that if the animal began consistently to choose one alternative, it was not exposed to the other except on forced trials. There is a possibility that this bias could lead to a situation where all reinforcers were earned by responding to that alternative and the obtained rate of reinforcement for the low-density key would become higher than the obtained rate of reinforcement for the high-density key, thereby guaranteeing continued

Fig. 3. Per cent choices for the low-density key for each subject in the uncorrelated group. The data are plotted across sessions. The first panel shows the results for the original training and the second panel shows the results following the change in the functions of the keys.

pecking on the low-density key. Although it is a mystery why this state of affairs might arise selectively in one group in Experiment I and not in the other, a better procedure that will control for this possibility seems called for. Concurrent variable-interval schedules in the initial component of concurrent chains schedules have been widely used in investigations of this sort since their introduction by Autor (1960, 1969). Given a reasonable rate of responding on both keys, this procedure ensures that the animal will be exposed to both alternatives equally often when the mean interval is the same in both initial links. This procedure was used in Experiment II to investigate preference for the low-density key.

METHOD

Subjects

Four female White Carneaux pigeons all had a brief history in another chamber of pecking at a key through which they could see grain. Two additional birds were started in the experiment but they developed a per-

Fig. 4. Per cent choices for the low-density side for the subjects that had previously been in the uncorrelated condition following exposure to the correlated stimuli on the low-density side.

sistent preference for the left side, despite several changes in the experimental variables, and were dropped from the experiment.

Apparatus

The apparatus was the same as for Experiment I.

Procedure

The key peck was shaped on unlit response keys. Birds II-1 and II-2 were trained in several sessions with forced exposure to each response key. For both of these birds, the left key was the low-density key and the right key was the high-density key. As in Experiment I, red and green lights appeared on the low-density key and were correlated with timeout and reinforcement, respectively. The white light appeared on the high-density key. Following the sessions of forced trials, the birds were placed on concurrent variable-interval schedules in the initial links of the schedule. The mean interval was 20 sec, with a range of 1 to 40 sec. Birds II-3 and II-6 were exposed to concurrent VI 20-sec schedules in the initial components after only enough preliminary training with food reinforced pecks on the unlit keys to ensure reliable key pecking.

Three variables were manipulated either between birds or for a single bird. The first of these was delay duration. This was always the same for each type of delay (red, green, or white) but assumed different values (5, 15, or 45 sec) for different birds and in different phases of the experiment. The second variable was the correlation of the green and red lights with reinforcement and timeout. This variable assumed one of two values, perfect correlation or no correlation, as in Experiment I. In the correlated condition, green was always followed by grain and red by timeout. The third variable was the percentage of delays on which food was delivered after a peck on the key on which the white light occurred. Values of 100% and 80% were used. On the occasions in the 80% condition when food was omitted, all other events except food delivery were the same as in the 100% condition.

Table 1 shows the different conditions to which the birds were exposed. It also gives the order of exposure and the number of sessions of exposure to each condition.

RESULTS

Relative rates of responding for all birds in all conditions are shown in Figure 5. The

Table 1

Number of sessions in each condition for each subject in each phase of the experiment. The delay duration, correlation of low-density key stimulus with reinforcement, and the percentage of reinforcement following white on the high-density key are given. Also given are the mean absolute rates of responding for each bird averaged over the last five sessions of a condition, the relative rate on the low-density key and the relative rate of reinforcement on the low-density key. In the response rate column, the low-density key is indicated by the word "Low" and the high-density key is indicated by the word "High".

Birds	No. of Sessions	Delay (Sec)	Correlated Stimuli	% S ^R in White	Response Rate		Relative Rate	
					Left Density Key High	Right Density Key Low	R(Low)/R(Total)	S ^R (Low)/S ^R (Total)
II-1	12	45	Yes	100	10.31	5.71	0.64	0.34
	10	45	No	100	2.23	2.78	0.45	0.25
	14	45	Yes	100	4.78	3.37	0.59	0.27
	15	15	Yes	100	18.73	15.73	0.55	0.55
II-2					Low	High		
	19	15	Yes	100	27.21	10.08	0.73	0.33
	14	15	No	100	11.25	25.67	0.30	0.32
	15	15	Yes	100	20.80	31.00	0.41	0.33
	15	45	Yes	100	22.91	26.56	0.46	0.33
	10	45	Yes	80	16.41	12.14	0.57	0.38
	15	45	Yes	100	9.51	3.96	0.71	0.33
II-3					High	Low		
	14	5	Yes	100	16.31	19.36	0.54	0.34
	10	15	Yes	100	11.75	27.29	0.70	0.35
	10	5	Yes	100	19.95	35.71	0.63	0.34
	15	5	No	100	21.80	21.76	0.50	0.32
	12	5	Yes	100	29.77	25.66	0.46	0.33
	18	15	Yes	100	28.19	38.95	0.58	0.33
II-6					Low	High		
	14	15	Yes	100	28.26	29.19	0.49	0.33
	15	15	Yes	80	37.52	24.03	0.61	0.38
	14	15	No	80	20.32	29.92	0.40	0.40
	10	15	Yes	80	32.80	20.55	0.62	0.38

relative rate is always expressed as the rate on the low-density key divided by the rates on both keys. Figure 5 presents the daily relative rates over the last five days in a given condition. Absolute rates and average relative rates of responding and relative rates of reinforcement are given in Table 1. All data given in Table 1 are the average of the last five sessions under a given condition. Since the birds underwent different sequences of procedures, each subject is discussed separately.

Bird II-1. This bird had some previous history of training with procedures of those of Experiment I, *i.e.*, FR 1 in the initial links. During this training the delay was manipulated. A delay of 45 sec was selected for Experiment II because it produced more pecking on the low-density key than any shorter delay

tested. This bird responded relatively more on the low-density key when the stimuli on that key were correlated with reinforcement and timeout than when they were uncorrelated. The data in the uncorrelated condition were highly variable, but generally the relative rate was much lower than in the correlated phases. The final panel for this bird shows the relative rate when the delay was shortened to 15 sec. The relative rate for these sessions appears to be somewhat lower than for the 45-sec delay conditions.

Bird II-2. This pigeon began with a higher rate on the low-density key when the delay was 15 sec and the stimuli correlated. The response rate was higher on the high-density key in the uncorrelated condition, but when the bird was returned to the correlated condition, it did not show a reversal of relative

Fig. 5. Relative rates for the last five sessions of a given condition for all birds in all conditions in Experiment II. All rates are calculated by dividing the responses on the high-density key by the total responses on both keys. Each panel gives the conditions under which the bird was run. Delay duration in seconds, whether the stimuli on the low-density side were correlated with reinforcement or not (correlated *versus* uncorrelated) and the percentage of reinforcement on the high-density side are given. If not otherwise indicated, the percentage of reinforcement following white is 100%. All cases where it is 80% are indicated by $H = 80\%$. The symbol "H" stands for high density.

rates of responding. Increasing the delay to 45 sec apparently had some effect but did not cause the relative rate to be higher on the low-density key. When the percentage of reinforcement following the white light on the high-density key was decreased from 100% to 80%, the rate became higher on the low-

density key. A final change was to increase the percentage of reinforcement following white from 80% back to 100%. The relative rate on the low-density key increased even further. Table 1 reveals that the absolute rates of responding decreased when this manipulation was made.

Bird II-3. There was only a modest preference for the low-density key in the first phase when the delay was set at 5 sec. Increasing the delay to 15 sec increased the relative rate on the low-density key and decreasing the delay to 5 sec lowered the relative rate on the low-density key. When the stimuli were uncorrelated on the low-density key, the relative rate on that key decreased to about 0.50 and did not increase when the stimuli were again correlated. Increasing the delay to 15 sec increased the relative rate on the low-density key.

Bird II-6. This bird had a relative rate of about 0.50 on the low-density key when the delay was 15 sec. Its relative rate on that key increased when the percentage of reinforcement following the white light on the high-density key was lowered to 80%. The relative rate became higher on the high-density key when the stimuli were uncorrelated on the low-density key, and returned to its previous value in the final phase when the stimuli were correlated.

DISCUSSION

The results of Experiment I indicate that pigeons may more often peck on a key that produces reinforcement only intermittently than on a key that always produces reinforcement. The results of this experiment cannot be attributed to the novelty or variety of the stimuli on the low-density key because a control group pecked more often on the high-density key when the stimuli on the low-density key were not correlated with reinforcement and timeout.

The results of Experiment II confirmed those of Experiment I, but with concurrent variable-interval chains instead of concurrent FR 1 chains. Several features of Experiment II should be noted. First, in comparing the results of the two experiments it can be seen that the results of Experiment I appear to show a stronger preference for the low-density key than Experiment II. Several birds in Experiment I responded on the low-density key on almost every occasion. In Experiment II, the relative rate of responding on the low-density key was seldom more than 0.60. In Experiment II, the concurrent variable-interval schedules in the initial links of the chains assured that the frequency of rein-

forcement for pecks on the high-density key would be relatively high. The frequency of reinforcement for the low-density key never exceeded 0.38, and this frequency occurred for the two subjects that were subjected to 80% reinforcement following white on the high-density key.

Another interesting aspect of the data is the failure to recapture a higher relative rate on the low-density key following the uncorrelated condition for two of the subjects. This failure could simply have been due to an insufficient number of experimental sessions, but some trend would have been expected within the number of sessions given, since a change in conditions often engendered a change in relative response rates within two or three sessions. It is unclear what variables besides an insufficient number of sessions could account for the result. In both cases, a further change in conditions did result in an increased relative rate on the low-density key. For Bird II-2, the change was to 80% reinforcement on the high-density key, and for Bird II-3, the duration of the delay was lengthened. It has been argued that pigeons do not attend to the stimuli on the response key under conditions where stimuli are uncorrelated with reinforcement contingencies (Honig, 1969). Perhaps in the uncorrelated condition in the present experiment the birds stopped attending to the key in the uncorrelated condition and attention was not restored until some relatively high-magnitude change in variables occurred.

There is some evidence from the data that the longer the duration of the delay the higher the relative rate on the low-density key. Some preliminary evidence from Bird II-2 was previously mentioned. Further evidence comes from Bird II-1, II-2, and II-3. When the delay was decreased for Bird II-1, its relative rate on the high-density key decreased somewhat. The delay was also lengthened for Bird II-2 from 15 to 45 sec from the third to the fourth phase. There appeared to be some increase in relative rate on the low-density key. A more systematic result was found with Bird II-3 where the delay was increased and then decreased again. The relative rate on the low-density key was higher under the 15-sec delay. The experiment was not intended to be a systematic exploration of delay, and the data are suggestive but not conclusive.

In Experiment II, an implicit criterion of "preference" has been adopted. If the birds respond with a relative rate of above 0.50 on a key it has been assumed that it prefers the consequences associated with that key. Another criterion, based on matching might have been adopted. Herrnstein (1964) showed, in a concurrent chains procedure, that the relative rate of responding on a key is proportional to the relative rate of primary reinforcement on that key. All primary reinforcers occurred during the terminal components of two-component concurrent chains. In Experiment II, the relative rate of reinforcement on the low-density key was about 0.33 in most of the conditions where the white light was always followed by reinforcement and about 0.38 where the white light was followed by reinforcement 80% of the time. The criterion of a relative rate above 0.50 to demonstrate preference is relatively conservative compared to a criterion based on the relative frequency of primary reinforcement, in which relative responding above 0.33 or 0.38 on the low-density key might be said to demonstrate preference. However, the relative rate of responding on the low-density key did not always match the reinforcement rate in the uncorrelated conditions, in which matching might be expected, so that a criterion of preference based on matching is not appropriate in these cases.

Wilton (1972) and Wilton and Clements (1971a) discussed the results of the Wilton and Clements (1971a) experiment in terms of an information hypothesis. Since the present experiments represent a "choice" version of their single key experiment, it is appropriate to inquire if the present results may be interpreted in terms of information. First, assume that information and uncertainty reduction are reciprocal terms. The delivery of information must imply the reduction of uncertainty. Secondly, it is assumed that the only event of intrinsic value in the present experiments was the delivery of food. The value of any other stimuli in the situation must be somehow related to the delivery of food to the pigeon.

Consider the arrangement of Experiment I in terms of uncertainty and uncertainty reduction. What is the pigeon uncertain about and what kind of uncertainty reduction is reinforcing? The control group of Experi-

ment I shows that it is not uncertainty about the key color *per se* that is reinforcing. If it were, then the control group should show the same preference for the low-density key as the control group. It must be uncertainty reduction about whether or not food delivery will be forthcoming that is reinforcing. But why should any uncertainty about the availability of food ever arise? Consider the bird just following reinforcement or timeout. If at that time it becomes uncertain about whether or not food will be delivered, any movement toward the high-density key should reduce that uncertainty because a peck on that key produces a stimulus always associated with food. However, it is still not clear why uncertainty should ever arise, because the pigeon is in a situation where it may always obtain food by pecking the high-density key. An information interpretation would have to insist that the bird is specifically concerned with reducing uncertainty about whether or not food will be delivered after a peck on the low-density key. Evidently, the explanation of the present data lies somewhere else.

Assume that in the present experiments, the green light and the white light are both conditioned reinforcers under the correlated condition. Are there any principles of conditioned reinforcement that would lead us to expect the present results? The probability of reinforcement given a positive stimulus (white or green) was the same in Experiment I and in most cases in Experiment II, so that this variable could not account for any preference. An experiment by Notterman (1950) provides a basis for a possible line of attack on the question. Notterman trained rats in a runway, giving them either reinforcement in the presence of a light or no reinforcement in the absence of light. Different groups of rats were given differing numbers of nonreinforced trials in the absence of the light, ranging from no nonreinforced trials to 100. Fifty trials were given on which running was reinforced. Following training, all groups were extinguished in the absence of the light. Finally, the light was made response-dependent for all animals. The outcome of the experiment was that the more discrimination training originally given, the more the light facilitated running during the final test. One interpretation of these data might be that the more time that an animal spends in a negative

discriminative stimulus in a particular environment, the more valuable will be any positive discriminative stimulus that alternates with the negative stimulus.

This interpretation may be applied to several observing response experiments. Eckerman (1973), Hendry (1965), Kendall (1973*b*), McMichael, Lanzetta, and Driscoll (1967), McMillan (1970), and Wilton and Clements (1971*b*) all found that as the proportion of time spent in the presence of negative stimuli increases, observing responses increase in strength. All of these studies varied the probability of the positive stimulus in an observing response procedure, but, as a by-product, the relative amount of time in each component was also altered. Kendall (1973*b*) pointed out that these studies confound the variations in stimulus probability with variations in the amount of time spent in the presence of the stimuli.

An observing response experiment by Kendall (1973*a*) varied the amount spent in the negative component but did not vary the probabilities of the components. It was found that the longer the negative component, the greater the strength of the observing response.

We might consider the session time in the present experiments divided into "positive time" and "negative time". Positive time would be all time spent in stimuli associated with primary reinforcement. This time would include time spent in the presence of the white and green lights plus the time when the feeder was raised. Negative time would be all time spent in stimulus conditions that were not directly associated with primary reinforcement. This would include time spent in the initial components of the chains, the time when the red light was on and the timeout. We might then assume that the value of positive time associated with one key increases as a function of increases in negative time associated with that key. On the high-density key, the positive time will be time in the white light and negative time will be that portion of time in the initial links spent responding on the high-density key. On the low-density key, positive time will be time spent in the green light. Negative time will include time spent responding in the initial link on that key plus the time spent in red. Reinforcement and timeout are not included because they

are not events specific to one key. Now it is clear that the ratio of negative time to positive time is greater on the low-density key than on the high-density key, but this does not solve all problems. The intermittency of reinforcement for variable-interval responding (or FR 1 responding) is greater on the low-density key. If we consider each peck (in Experiment I) or each completed variable-interval segment (in Experiment II) to be a "unit" of responding, then each complete unit on the high-density key receives reinforcement, but only half of the units on the low-density key receive reinforcement. It must be assumed that the advantage gained for the green light by being alternated with the red light must outweigh the deleterious effects of intermittent reinforcement for that key. This assumption seems plausible in the light of single-key experiments where a completed schedule reinforcement is reinforced intermittently (*e.g.*, Zeiler, 1972). Extrapolation from single-key experiments to concurrent arrangements should be viewed with caution, however.

An alternative approach to interpretation of these data might run as follows. It is not the increased value of the positive delay stimulus on the low-density key that is responsible for the higher relative rate on that key. The higher rate reflects some after-effect of being exposed to the negative delay period. Catania (1961) found that when a concurrent schedule with variable-interval schedules on both keys is changed to a concurrent schedule with variable interval on one key and a multiple schedule on the other, behavioral contrast may result on the key changed to the multiple schedule. In his experiment, the multiple schedule consisted of variable-interval and extinction components. Since, in the present experiment, responding on the low-density key is occasionally interrupted by a negative stimulus (red light and timeout) contrast might selectively occur on that key. The fact that the negative delay stimulus is response-dependent is incidental. This is true for the previous hypothesis as well because the value of the green is assumed to be a function of the total negative time, regardless of whether stimuli associated with that time are response-dependent or not.

We will call the first hypothesis presented the value hypothesis and the second the con-

trast hypothesis. Two ways of distinguishing between the value and contrast hypotheses may be suggested. The use of concurrent schedules with a changeover key might be appropriate (Findley, 1958). The fact that a pigeon pecks more in a component does not necessarily mean that it prefers that component (Arnett, 1972; Fantino, 1969), but if a given component is preferred, the bird should spend more time in it in addition to pecking at a higher rate in the concurrent schedule used in the present experiments.

Another procedure, currently under investigation, is to allow switching in only one direction, from the high-density component to the low-density component with automatic return to the high-density component. The value hypothesis suggests that the pigeons should regularly switch to the component with the correlated stimuli because only in that component can it obtain the highly valued event, the stimulus that is alternated with a stimulus correlated with no food.

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