CHOICE AND MULTIPLE REINFORCERS

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Pigeons chose between equivalent two-component mixed and multiple terminal-link schedules of reinforcement in the concurrent-chains procedure. The pigeons preferred the multiple schedule over the mixed when the components of the compound schedules were differentiated in terms of density of reinforcement, but the pigeons were indifferent when the components were differentiated in terms of number of reinforcers per cycle. Taken together, these results indicate that a local variable, the interval to the first reinforcer, but not a molar variable, the number of reinforcers, was sufficient to differentiate the components and thereby evoke preference.

Key words: choice, concurrent chains, multiple schedules, number of reinforcers, key peck, pigeons

Recent research using both the observing response procedure and the concurrent-chains choice procedure indicates that animals typically prefer stimuli that are correlated, rather than uncorrelated, with differing conditions of reinforcement (see Fantino, 1977, for a review). In general, this research has shown that the development of such preference is a function of two rather broadly defined sets of variables: (a) those influencing the reliability and validity of the stimuli themselves, and (b) those influencing the degree to which the background conditions of reinforcement are actually different. Both sets of variables have been the topic of considerable experimental investigation. For example, with regard to the first set, Kendall (1973) parametrically varied the probability of food presentations and blackouts in the presence of each stimulus in an observing response situation and found that observing decreased to near zero levels as the probability of the two events in the presence of each stimulus approached .50. Thus, observing decreased as one stimulus ceased to be correlated systematically with food presentation and the other with blackout, i.e., as the stimuli

became unreliable, invalid predictors of the events.

The second set of variables, those pertaining to the background conditions of reinforcement, has perhaps been more heavily investigated. For example, the observing-response literature indicates that animals will convert a mixed schedule to a multiple schedule by means of an observing response when (a) responses are punished in one component but not in the other (Dinsmoor, Flint, Smith, & Viemeister, 1969); (b) reinforcers are available in one component but not in the other (Dinsmoor, Browne, & Lawrence, 1972); (c) the rate of reinforcement is higher in one component than in the other (Kendall & Gibson, 1965); (d) the magnitude of reinforcement is greater in one component than in the other (Auge, 1973); and (e) response effort is greater in one component than in the other (Perone & Baron, 1980). Similarly, the concurrent-chains choice literature indicates that animals will respond more during the concurrently available initial links on a key that leads to a multiple terminal-link schedule than on a key leading to a corresponding mixed terminal-link schedule when reinforcers are available in one component but not in the other [Green & Rachlin, 1977; cf., parameter (b) above], and when the rate of reinforcement is higher in one component than in the other [Fantino & Moore, 1980; cf., parameter (c) above]. Experiments indicating that animals will prefer a multiple schedule over a corresponding mixed schedule when

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components differ on the basis of variables (a), (d), and (e) above remain to be performed.

The present research attempted to determine whether number of reinforcers was a variable in this second set that would functionally differentiate conditions of reinforcement. As in other research, the concurrent-chains choice procedure was used. Pigeons' pecks on either key during the concurrently available initial links produced a terminal link offering either few or many reinforcers on that cycle. The difference between the terminal links was that for one, there was only one stimulus, uncorrelated with number of reinforcers, but for the other, there were two stimuli, correlated with the number of reinforcers. Thus, the pigeons were effectively choosing between mixed and multiple terminal-link schedules of reinforcement, where the designations mixed and multiple refer to whether the stimuli were uncorrelated or correlated with number of reinforcers per cycle, rather than with rate of reinforcement. At issue was whether the pigeons would prefer the multiple schedule in such comparisons, as they had in the research reviewed above. To the extent that they did, then number of reinforcers could be added to the list of variables that evoke preference in such settings.

Whether one expects that the pigeons would indeed prefer the multiple schedule or that they would be indifferent is to some extent a function of one's conception of the principle of reinforcement. For example, Baum (1973) has suggested that reinforcement be interpreted in terms of a scale of molar value. Thus, to say that x is more reinforcing than y is to say that x is more valued than y , where value is a complex function of many variables pertaining to reinforcement and punishment in situations x and y . Now, preference for a multiple schedule over a corresponding mixed schedule ordinarily occurs when the components of the schedules are sufficiently differentiated in terms of reinforcement/punishment, or to use Baum's language, when the two components are sufficiently differentiated in terms of value. Can it be said that, in the present procedure, the two components offering different numbers of reinforcers are of different values? The thrust of the present argument is yes, because according to a molar view, a larger number of reinforcers in one component means a greater net ecological feedback

for the response that produced that component, and that relation virtually defines a greater molar value (Baum, 1973, pp. 148-149). Thus, it follows that in the present choice test, the components of the terminal-link schedules should be sufficiently differentiated in terms of value. Given that the components are sufficiently differentiated, then it further follows that the animals should prefer the informative condition (i.e., the multiple terminal-link schedule), despite the absence of any difference in primary reinforcement between the terminal links, in the same way that the animals prefer multiple schedules over mixed schedules when the different values of the components are produced by differences with respect to any other parameter, such as rate of reinforcement (cf., Baum, 1973, p. 152).

In contrast, an argument can also be made that the animals should be indifferent. In some recently reported research (Moore, 1979), pigeons chose directly between a large number of reinforcers in one terminal link and a small number in the other of a concurrent-chains procedure. The major finding was that preferences were not influenced by overall number of reinforcers per se in each terminal link, but rather by the interval to the first reinforcer in each terminal link. This finding, if general, appears to constitute a major limitation regarding a molar conception of reinforcement, according to which the pigeons should have been integrating all feedback over time and arriving at a higher value for the terminal link with more reinforcers (cf., Baum, 1973). To the extent that this finding may be extended to the present procedure, if a greater number of reinforcers per se does not impart a greater value to one component of the terminal-link schedule, then the animals may well be indifferent.

In addition to addressing the empirical issue of what factors evoke preference for multiple schedules over mixed, the present choice comparisons implicitly provide an empirical test of the generality of recent theoretical assertions regarding the kinds of independent variables to which animals respond (e.g., Baum, 1973). In the present comparisons, if the animal does not respond to number of reinforcers in the way required by these theoretical assertions, the generality of those assertions must be viewed as severely limited. The present procedure, therefore, serves as an

effective, sensitive technique for identifying whether some parameter of reinforcement has functional significance with respect to the control of behavior. If the parameter will serve as the basis for establishing a preference by differentiating the components, then presumably the parameter is functionally significant. If it will not so serve, its generality as an effective controlling variable is suspect.

METHOD

Subjects

Three adult male pigeons of mixed breeds and various experimental histories (P-15, P-21, P-9) were maintained at approximately 80% of their free-feeding weights. Pigeon P-9 died during the experiment; the data from the comparisons that it finished have been included.

Apparatus

A two-key version of the standard operant chamber for pigeons was used. Conventional electromechanical programming apparatus, located in a room adjacent to the chamber, controlled events within the chamber and recorded the data.

Procedure

The present choice comparisons were carried out using the concurrent-chains procedure. In this procedure, the pigeon is presented with two concurrently available response keys, each illuminated by a stimulus associated with the initial link of a chain. Occasionally, a peck on one key produces a terminal-link stimulus and the other key becomes dark and inoperative. Further responding on the illuminated key produces food; at the completion of the terminal link, the initial links are reinstated and the cycle begins anew. The independent variable is typically some difference between the ways in which food is achieved in the terminal links, and the dependent variable is the distribution of responding in the concurrent initial links, called the choice proportion. The choice proportion is generally expressed as a ratio in the form of $R_L/(R_L + R_R)$. The pigeons are said to be indifferent between the terminal links when the choice proportion approximates .50 and to exhibit a preference for a given terminal link when choice proportion in favor of that terminal link reliably exceeds .50.

Figure 1 presents the sequence of events in the present application of the concurrent-chains procedure. During the initial links, non-independent VI 30-sec schedules were in effect (Stubbs & Pliskoff, 1969). Whenever the pigeon entered either terminal link, an independently programmed probability device (probability gate set at .5 throughout) determined whether the component produced on that terminal-link entry would yield a large number of reinforcers or a small number. Procedurally, the number of reinforcers per component was arranged by having the terminal link in effect for a short period of time, i.e., a short component, or a long period of time, i.e., a long component. The duration of the component in conjunction with the interreinforcement interval (IRI) of the schedule in effect during that component then determined the number of reinforcers that the pigeon would achieve on that cycle (Moore, 1979). Thus, to use the same schedule values and durations as does the figure, if the apparatus determined the short component should be in effect, a VI 30-sec schedule was in effect for a fixed duration of 30 sec. After

Fig. 1. The sequence of events and representative VI schedule/component durations are shown for the experimental procedure. During the terminal links, either a short duration or a long duration component was in effect. A probability gate, set at $p = .5$ throughout, operated during the transition between each initial and terminal link and randomly determined the component duration. Terminal-link stimuli were either correlated (mult schedules) or uncorrelated (mix schedules) with respect to component duration/number of reinforcers.

Table 1

The schedules to which each pigeon was exposed are listed. Included are the terminal-link VI schedules (preceding the slash) and the component durations (following the slash), and whether the stimuli in the left (L) and right (R) terminal links were correlated (mult) or uncorrelated (mix) with respect to the length of the components. The initial links were always VI 30-sec schedules. All terminal link VI schedule values and component durations are in seconds. (* indicates subject died before comparisons could be conducted).

Pigeon	Short: VI 30/30 Long: VI 180/180		VI 30/30 VI 30/180		VI 30/15 VI 30/180		VI 30/30 VI 180/180	
	L	R	L	R	L	R	L	R
P-15	mix	mix	mix	mix	mix	mix	mult	mix
	mix	mult	mult	mix	mix	mult	mix	mult
	mult	mix	mix	mult	mult	mix		
P-21	mix	mix	mix	mix	mix	mix	mult	mix
	mult	mix	mix	mult	mix	mult		
	mix	mult	mult	mix	mult	mix		
P-9			mix	mult				
	mix	mult	mix	mix	*		*	
	mult	mix	mult	mix				
			mix	mult				

this period, the initial links were reinstated. If the apparatus determined that the long component should be in effect, a VI 30-sec component was in effect for a fixed duration of 180 sec. For convenience, these components will be designated in the format of VI 30/30 and VI 30/180. As in earlier research (Moore, 1979), VI tapes in the present experiment were constructed according to Segal's (1964) method. The focal comparisons of the experiment were those in which prevailing stimuli in one terminal link were correlated with the short and long component durations, and hence correlated with number of reinforcers, and the single stimulus in the other terminal link was uncorrelated with the short and long component durations, and hence uncorrelated with number of reinforcers. When the terminal link stimuli were correlated with duration, the terminal-link schedule is designated as a multiple (mult) schedule, and when uncorrelated, as a mixed (mix) schedule.

Table 1 presents an overview of the conditions in the experiment. All pigeons were exposed to VI 30/30 and VI 180/180 at least once. This comparison was used as a simple control condition to indicate that the pigeons would indeed respond in a way that was consistent with that observed in other procedures (Fantino & Moore, 1980). That is, on the basis of previous research, it was fully expected that the pigeons would prefer the multiple schedule over the mixed in this comparison. The two important experimental comparisons, and

the comparisons that produced new data, were the comparisons in which (a) the short component was VI 30/30 and the long was VI 30/180, and in which (b) the short was VI 30/15 and the long was VI 30/180. In a VI 30/30 component, one reinforcer per cycle would typically be achieved. In a VI 30/180 component, six reinforcers per cycle would typically be achieved. Similarly, in a VI 30/15 component, one reinforcer every other cycle would typically be achieved. Use of the VI 30/15 component approximates a percentage-reinforcement procedure, although the present procedure does differ slightly in that the probability of a reinforcer in one component is .5, rather than 0 as in percentage reinforcement (cf. Moore, 1976).

Pigeons P-15 and P-21 were exposed to the components in the following order: (a) VI 30/30 and VI 180/180, (b) VI 30/30 and VI 30/180, (c) VI 30/15 and VI 30/180, (d) VI 30/30 and VI 180/180. P-9 was exposed to (a) VI 30/30 and VI 30/180, and then (b) VI 30/30 and VI 180/180. As indicated in Table 1, P-9 died before further comparisons could be conducted. Certain control procedures, such as frequent reversals and mix vs. mix conditions (e.g., when the components were VI 30/30 and VI 30/180 and when they were VI 30/15 and VI 30/180), are shown in Table 1. In conditions when the long component was VI 180/180, sessions were terminated after the pigeon had received 20 reinforcers. In conditions when the long component was VI 30/180, sessions were terminated after the pigeon had received

Table 2

The schedules and data are listed for individual pigeons in the experiment. Included are the VI schedules/component durations, whether stimuli in the left (L) and right (R) terminal links were correlated (mult) or uncorrelated (mix) with respect to component duration, the absolute rate of responding (responses per min) in the initial links and in the terminal-link components, the initial-link choice proportions (in favor of mult; if mix vs. mix, then in favor of right key), and the number of sessions in each determination. The data are averages from the last three sessions of each determination. All terminal link VI schedules/component durations are expressed in seconds. Pigeons were exposed to the schedules in the order listed.

VI Schedule/ Component Duration	Stimuli in Terminal-link Schedules		Responses Per Min						Initial Link Choice Proportion	Sessions	
	L	R	Initial Link		Left Terminal		Right Terminal				
			L	R	Short	Long	Short	Long			
<i>Pigeon P-15</i>											
SHORT: VI 30/30	Mix	Mix	13	15	43	38	42	27	.55 (R)	24	
LONG: VI 180/180	Mix	Mult	25	22	62	51	46	42	.47	17	
	Mult	Mix	43	9	84	60	52	53	.83	15	
SHORT: VI 30/30	Mix	Mix	30	22	69	61	70	54	.42 (R)	10	
LONG: VI 30/180	Mult	Mix	23	19	67	60	57	44	.54	15	
	Mix	Mult	21	19	80	70	71	52	.48	15	
SHORT: VI 30/15	Mix	Mix	22	26	78	73	68	43	.53 (R)	10	
LONG: VI 30/180	Mix	Mult	39	39	17	87	56	43	.50	15	
	Mult	Mix	30	25	82	59	12	60	.54	15	
SHORT: VI 30/30	Mult	Mix	77	36	73	92	72	62	.66	15	
LONG: VI 180/180	Mix	Mult	36	71	71	64	98	62	.67	24	
<i>Pigeon P-21</i>											
SHORT: VI 30/30	Mix	Mix	22	23	84	49	86	86	.52 (R)	10	
LONG: VI 180/180	Mult	Mix	55	7	265	63	140	116	.88	15	
	Mix	Mult	30	67	197	122	215	85	.68	19	
SHORT: VI 30/30	Mix	Mix	47	41	146	120	148	140	.47 (R)	10	
LONG: VI 30/180	Mix	Mult	26	26	157	124	154	98	.50	15	
	Mult	Mix	27	25	159	144	145	140	.52	23	
	Mix	Mult	51	43	252	201	187	118	.47	15	
SHORT: VI 30/30	Mix	Mix	44	45	200	119	168	135	.50	10	
LONG: VI 30/180	Mix	Mult	38	41	193	104	143	102	.51	23	
	Mult	Mix	9	10	237	97	121	93	.51	25	
SHORT: VI 30/30	Mult	Mix	68	44	186	82	85	104	.61	18	
LONG: VI 180/180											
<i>Pigeon P-9</i>											
SHORT: VI 30/30	Mult	Mix	16	16	109	58	65	67	.53	20	
LONG: VI 30/180	Mix	Mult	15	14	71	57	50	65	.45	16	
SHORT: VI 30/30	Mix	Mult	29	80	57	55	115	44	.74	15	
LONG: VI 180/180	Mult	Mix	41	30	85	52	72	56	.58	18	

60 reinforcers. In both cases, sessions were approximately 1 hr in length. Sessions were conducted six days per week. The reinforcer was 3-sec access to mixed grain. A stability criterion was used to assess steady state performance in the mix vs. mult conditions. This criterion required that the pigeon perform in at least 15 sessions. After the 15th session, or every session thereafter if the criterion was not satisfied, the choice proportions from the last nine sessions were considered in three blocks of

three sessions each. When mean choice proportions of the blocks differed by no more than .05 and showed neither a monotonically increasing nor decreasing trend, performance was judged stable.

RESULTS

Table 2 presents the data from individual pigeons, averaged across the last three sessions of each condition in the experiment. The

Fig. 2. The choice proportions are shown for each pigeon in each comparison of the experiment. The data are taken from Table 2 and are plotted in terms of the mult terminal link. The dotted line represents indifference. Bars above the dotted line indicate preference for mult; bars near the dotted line indicate indifference between the terminal links. Individual bars are presented for each determination.

choice proportions for the mix vs. mult comparisons are also presented in Figure 2. Both Table 2 and Figure 2 show that with the exception of P-15 on the initial determination, the pigeons preferred mult VI 30/30 VI 180/180 over the corresponding mix schedule. P-15 did prefer the multiple schedule after the reversal. This finding of preference replicates others already in the literature. All three pigeons, however, were indifferent between mult VI 30/30 VI 30/180 and the corresponding mix schedule. That is, the pigeons were indifferent when the components were differentiated in terms of number of reinforcers, such that the short component yielded one, and the long yielded six, reinforcers per cycle. The two pigeons that were exposed to VI 30/15 and VI 30/180 components were also indifferent. That is, the pigeons were indifferent even when the short component yielded less than one reinforcer per cycle, in a procedure approximating percentage reinforcement. The pigeons' preferences for multiple VI 30/30 VI 180/180 were re-established after the VI 30/15 VI 30/180 comparisons, and as before,

the pigeons did prefer the multiple terminal-link schedule, replicating the known finding.

As seen in the Table 2, frequent reversals and mix vs. mix control conditions were conducted in order better to assess the nature of observed preferences. As mentioned above, P-15 was indifferent between mult VI 30/30 VI 180/180 and the corresponding mixed schedule on the initial exposure, but did prefer to the multiple schedule on the reversal. P-15's preference for the multiple schedule in the last set of conditions appeared readily and tracked the reversal in a fairly systematic way.

The behavior of P-21 and P-9 seemed extremely systematic throughout the experiment. Preferences for mult VI 30/30 VI 180/180 over the corresponding mixed schedule developed in a straightforward manner, and then both pigeons were indifferent when the components were VI 30/30 and VI 30/180. Note the general stability of P-21's behavior, even after an additional reversal. P-21 continued to be indifferent when the short component was VI 30/15, replicating the data of P-15.

DISCUSSION

The present experiment found that pigeons were indifferent between mixed and multiple terminal-link schedules when the components were differentiated in terms of number of reinforcers, but that pigeons did prefer the multiple schedule when the components were differentiated in terms of density of reinforcement. These findings confirm and extend the generality of earlier findings (Moore, 1979), and re-emphasize the central role of local variables such as the interval to the first reinforcer, rather than the role of molar variables such as overall number of reinforcers, in the control of behavior.

These results should not be taken to mean that the interval to the first reinforcer is the only variable that can ever influence behavior, however. For example, Kendall (1967), using a single-key procedure, examined responding during the initial link of a two-link chain schedule with and without a second reinforcer in the terminal link. Initial-link rate of responding was higher with a second reinforcer than without. Similarly, Shull, Spear, and Bryson (1981) trained pigeons using a two-key procedure, where responses on one key produced reinforcers according to a variable-interval

schedule, and responses on the second key produced an alternative condition, which was then in effect for a fixed duration of time. Reinforcers were distributed in various ways during this alternative period. The pigeons pecked more on the second key when the delay from the first reinforcer to the second in the alternative condition was short than when it was long. Thus, these two experiments have shown that with a constant delay to the initial reinforcer, there is nevertheless an orderly change in rate of responding as a function of the temporal locus of subsequent reinforcers. That reinforcers after the first influenced rate of responding at all, given Moore (1979) and the present results, is important. The central issue is not so much whether one set of results is correct or incorrect, but rather the nature of experimental variables that are in control in each case.

The present results also have implications for the molar analysis of behavior generally and for molar conceptions of reinforcement particularly. According to Baum (1973), organism-environment interactions may be likened to a feedback system:

an organism can be viewed as collecting time samples of the significant events in its environment (e.g., reinforcers and punishers), which it integrates and utilizes to control its behavioral output. The exact nature of this integrating or averaging process has been the subject of some recent research. (p. 148)

Rate is the universal dimension. The rate of occurrence of a reinforcer, punisher, or discriminative stimulus can control behavior just as the other attributes of the event can control behavior. The organism, in other words, integrates all feedback over time. (p. 149)

In the present comparisons where there were equal VI schedules in the two components, there was clearly a net advantage to staying in the longer terminal link. The pigeon would not then have to go back to the initial links, respond until it had satisfied the initial-link schedule, and then re-enter the terminal links to resume responding for reinforcers (e.g., Thomas, 1966). If recent molar accounts of reinforcement are correct, then the pigeon should have indeed been sensitive to the number of reinforcers its behavior produced, since these accounts have asserted that animals are

sensitive to differences between rates of reinforcement, and the notion of rate entails the number of events divided by time. Although pigeons are not totally insensitive to the number of reinforcers their behavior produces, as shown by Kendall (1967) and by Shull et al. (1981), it is becoming increasingly clear that the way they are sensitive to number of reinforcers is not the way suggested by a molar view of reinforcement (McDiarmid & Rilling, 1965; Moore, 1979). Additional research on this issue will presumably clarify the manner in which reinforcers over time do control behavior.

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