OPTIMIZATION VERSUS RESPONSE-STRENGTH ACCOUNTS OF BEHAVIOR

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Pigeons were run in both single-key and concurrent-key experiments in which, over most of the range of response rates, an increase in response rate gave rise to a continuous decrease in reinforcement rate. In spite of the fact that a low response rate would have produced a high reinforcement rate, all birds responded at relatively high rates, thus keeping reinforcement rates substantially below the maximum possible. In the concurrent-key experiment, in addition to responding at relatively high rates, the birds' ratios of responses approximately matched the corresponding ratios of obtained reinforcers. The results are inconsistent with most theories of optimal performance, which assume that organisms behave in ways that either maximize reinforcement value or minimize deviations from a free-behavior point. On the other hand, the results are consistent with the assumption that reinforcement strengthens the tendency to respond.

Key words: matching law, optimization, concurrent schedules, single schedules, key peck, pigeons

In general, theoretical accounts of operant behavior may be said to fall into one of two categories: those that view reinforcement as strengthening immediately preceding behavior, and those that view behavior as tending either to minimize deviations from a free-behavior point (as expressed under a situation with few or no constraints) or to maximize reinforcement value.

The strengthening notion of reinforcement was championed by Skinner (e.g., 1938; Ferster & Skinner, 1957), who performed extensive analyses of relationships between reinforcement and rates of responding. There was implicit in Skinner's work a division of stimuli into those whose presentation was reinforcing, those whose removal was reinforcing, and those having neither effect.

Premack (1959, 1965, 1971) advocated an alternative, relativistic approach to reinforcement, arguing that behavior itself could be reinforcing and that the same behavior

might act as a reinforcer in one situation and a punisher in another. Briefly, he proposed that the probability of engaging in a particular activity was a measure of the value of that behavior, and that access to activities of higher value could reinforce those of lower value, while constrained participation in those of lower value could be used to punish behavior of higher value. Premack also introduced the notion of the free-behavior point: the distribution of behavior seen when no constraints are present. This baseline, according to Premack, could then be used to estimate changes in the probabilities or frequencies of various behavior patterns when schedule constraints were imposed.

Eisenberger, Karpman, and Trattner (1967), as well as Timberlake and Allison (1974), have argued that Premack's analysis, although clearly in the right direction, was nevertheless flawed (see also Dunham, 1977). Rather than asserting that higher-probability behavior would invariably reinforce lower-probability behavior, they claimed that an organism must be deprived of a particular type of behavior, regardless of its baseline probability, if access to that activity is to be reinforcing. Thus, in a contingent situation, engaging in an instrumental

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response with a consequent opportunity to perform the contingent response would result in an increase in the frequency of the instrumental response only if contingent responding was below baseline. This increase had appeared to earlier theorists (e.g., Skinner) as a strengthening effect on the instrumental response. In reality, according to response deprivation theorists, the observed increase allowed the organism to move closer to its baseline condition, thereby revealing the implicit adaptiveness of such behavior. More recently, Timberlake (1980) and Hanson and Timberlake (1983) have suggested that both instrumental and contingent behavior patterns have naturally occurring set points. Behavior seen under schedule constraints represents the animal's attempt to approximate the equilibrium represented by those points. In what follows, this position will be referred to as an equilibrium analysis.

An essentially similar approach has been taken by Staddon (1979, 1983). According to his position, behavior seen under continuous reinforcement (CRF—each occurrence of the response is reinforced) may be defined as a free-behavior point. Under other constraints such as variable-interval (VI) or variable-ratio (VR) schedules, the animal is said to minimize, so far as possible, the distance between the point representing its response rate and reinforcement rate, and the free-behavior point. A straightforward implication of this approach is that a high rate of reinforcement, in conjunction with a low rate of responding, should be chosen over a low rate of reinforcement in conjunction with a high rate of responding.

Finally, it has been suggested that response rates on single-key schedules are such that value is maximized (e.g., Baum, 1981; Rachlin, 1978; Rachlin, Battalio, Kagel, & Green, 1981). For example, indifference contours may be used to represent points of equal value. Given a schedule, the point at which the schedule is tangent to an indifference contour defines the maximum value obtainable on that schedule, and so that point should be preferred to other possi-

ble combinations of response rate and reinforcement rate.

All three theoretical approaches cited thus far (equilibrium, minimization of distance, maximization of value) have been based on experiments that employed either interval or ratio schedules. It is characteristic of these schedules that an increase in response rate will produce an increase in reinforcement rate. That is, within the coordinates of reinforcement rate as a function of response rate, these schedules have positive slopes. Such positive slopes are integral to the conclusions drawn, because the observed rates of responding on such schedules are explained on the basis of their having produced a higher rate of reinforcement than would otherwise occur. That higher rate of reinforcement is said either to bring behavior closer to its equilibrium point, minimize the distance from the free-behavior point, or lead to maximization of value.

It is possible, however, to program schedules not having a positive slope within the above coordinates. As usually programmed, a VI schedule is a negatively accelerated function with positive slope, having its asymptote at the programmed rate of reinforcement (see, for example, Baum, 1973, Figure 2). Vaughan (1976) employed what may be termed *linear* VI schedules—schedules having zero slope over most of their range. It is possible to program such schedules by running the VI tape continuously (except during the delivery of reinforcement) and storing reinforcements that are read from the tape, rather than stopping the tape when a reinforcement is read, as is the usual practice. It turns out that response rates on such linear schedules are within the same range as those seen on the more usual VI schedules. As Prelec (1983) pointed out, this outcome is inconsistent with a maximization analysis of behavior on such schedules, because that analysis (as well as the others discussed above) depends on the schedule having a positive slope. Given a schedule with zero slope, such analyses predict that response rate will approximately equal reinforcement rate (e.g., 1 response

per minute on a linear VI 1-min schedule), because an increase above that rate does not increase rate of reinforcement, and hence cannot (for example) bring the animal closer to its free-behavior point.

It is possible to go even further and program schedules having negative slopes: above some low rate of responding (which maximizes rate of reinforcement), an increase in response rate will result in a decrease in reinforcement rate. Under such schedules, the three analyses discussed above make unambiguous predictions: Response rate should be maintained at that low rate which maximizes rate of reinforcement. Any increase above that low response rate would violate those analyses along two dimensions: Reinforcement rate would be lower than the schedule constraint dictates, and response rate would be higher than the schedule constraint dictates. It is difficult to conceive of a stronger challenge to those approaches, couched as it is within the coordinates with which they were explicitly designed to deal.

It is possible to program a schedule with negative slope by starting with a linear VI schedule and subtracting a ratio schedule. Recall that a linear VI employs what may be termed a store—a count of the number of reinforcements currently available. A VI tape runs continuously and increments the store whenever reinforcement is read from the tape; the store is decremented whenever a response delivers one of the one or more that have been stored. A ratio tape (driven by responses, rather than time) may now be run, in parallel with the VI tape. Whenever the ratio tape reads a hole, a reinforcement is decremented from the store (which may drive the store into a negative state). The obtained rate of reinforcement is thus that programmed by the VI tape, less a rate that is proportional to the response rate (i.e., as determined by the ratio tape). Given a response rate such that the frequency with which holes are read from the ratio tape equals that with which they are read from the interval tape, the obtained rate of reinforcement will equal zero. In the present ex-

periments a fixed ratio (FR), rather than a variable ratio, was subtracted from the linear VI schedule, because it seemed unlikely the birds would be sensitive to periodicities of reinforcement decrement.

It should be pointed out that the property that an increase in response rate can result in a decrease in reinforcement rate is not unique to negative-slope schedules. It is shared by differential-reinforcement-of-low-rate (DRL) schedules. In fact, negative-slope schedules bear the same relation to DRL schedules that ratio schedules bear to differential-reinforcement-of-high-rate (DRH) schedules. In the case of differential-rate schedules, reinforcement is contingent upon the emission of a particular interresponse time (IRT). Given some average rate of responding, it is necessary to know the distribution of IRTs (i.e., what proportion of responses satisfied the contingency) before reinforcement rate can be predicted. With both ratio schedules and negative-slope schedules, on the other hand, reinforcement is an increasing function of, or a decreasing function of, response rate, independent of the distribution of IRTs (excluding pathological patterns). Negative-slope schedules thus constitute a natural complement to ratio schedules.

EXPERIMENT 1

In this experiment, pigeons were run on single-key schedules with negative slopes, derived from subtracting FR schedules from linear VI schedules. The primary question was whether the predictions of equilibrium analysis, minimization of deviations from a free-behavior point, and maximization of value would be confirmed on schedules the effects of which on behavior were unknown at the time those theories were developed.

Subjects

Six White Carneaux and three homing pigeons were used, with two of the former and one of the latter in each of three conditions. All subjects had prior experimental histories and were maintained at approximately 80% of their free-feeding weights.

Apparatus

A standard pigeon chamber, 28 cm wide, 30 cm long, and 30 cm high, was used, with a single key, 1.9 cm in diameter, 21 cm above the floor, centered on the front wall above a standard grain magazine. A force of about 0.14 N was required to operate the key, which was transilluminated with two 7-W red bulbs. Each response produced an auditory feedback click. The chamber was illuminated by two 7-W white bulbs except during reinforcement, when only the magazine was illuminated. White noise and a fan masked extraneous noise. The experiment was controlled by means of electromechanical equipment in conjunction with a PDP-8 computer.

Procedure

Each bird was run on three linear schedules with equal negative slopes but with differing intercepts. The schedules were generated by means of subtracting FR schedules (which are linear) from linear VI schedules. The linear VI schedules used were as follows: VI 30-s (120 reinforcements per hour); VI 45-s (80 reinforcements per hour), and VI 90-s (40 reinforcements per hour). Each VI schedule consisted of 16 intervals from Fleshler and Hoffman (1962). When a reinforcement was read from the VI tape, it was stored and the tape continued to advance. When the FR schedule was satisfied, one reinforcement was subtracted from the store, regardless of the current state of the store. A response that occurred when one or more reinforcements were stored produced immediate reinforcement and decremented the store by one. A minimum of 5 s had to elapse between the presentation of one reinforcer and the next, thereby preventing the collection of a number of reinforcers in immediate succession. Sessions ended after 40 reinforcers or 40 min (excluding reinforcement time), whichever occurred first. Reinforcement consisted of 3-s access to mixed grain. Birds were run 7 days a week.

For one group of birds, the subtractive schedule was FR 20; for the second, it was

FR 40; for the third group it was FR 60. Thus, for the first group, each increase in response rate of 20 responses per min resulted in a decrease in reinforcement rate of 1 per min, or 60 per hr. Given a linear VI 30-s schedule (120 reinforcements per hr), a response rate of 40 responses per min should be just sufficient to drive reinforcement rate to zero. A response rate of approximately 2 per min should produce a reinforcement rate of approximately 114 per hr (120 per hr from the VI 30 less 6 per hr from the FR 20), the maximum possible rate on such a schedule. At the end of 60 sessions (or, for subsequent conditions, 20 sessions), the schedules were changed when response rates appeared stable.

Table 1 shows the schedules on which each bird was run and the total number of sessions. During the first condition it was apparent that the birds tended to respond faster than was optimal. For that reason they were exposed to that condition for a minimum of 60 sessions, on the assumption that more time might allow them to learn the negative correlation between changes in response rate and changes in reinforcement rate.

After exposure to linear schedules with negative slopes, each bird was run on linear VI schedules with flat slopes. The rates of reinforcement provided by the schedules

Table 1
Schedules and number of sessions for each bird in Experiment 1

Schedule	Subject		
	19	47	93
VI 30-s FR 20	65	67	69
VI 45-s FR 20	23	23	23
VI 60-s FR 20	24	24	36
	140	150	94
VI 30-s FR 40	71	63	70
VI 45-s FR 40	23	23	23
VI 60-s FR 40	41	36	39
	52	279	95
VI 30-s FR 60	71	66	70
VI 45-s FR 60	23	23	28
VI 60-s FR 60	36	36	32

were equated to those provided by the previous schedules. Those results (reported in Vaughan, 1982) are not germane to the present discussion and so will not be mentioned further.

RESULTS AND DISCUSSION

For each of the nine birds, Figure 1 shows the schedules on which each bird was run, as well as the response rates and reinforcement rates averaged over the last five sessions of each condition. In general, the data points fall close to the functions, indicating that the schedules worked approximately as planned. Deviations of the data points from the schedule functions may be due to the fact that the schedules for any given day did not resume where they had terminated the pre-

vious day. In particular, each session began with the store set to zero.

The most striking feature of these data is that all birds responded substantially faster than optimal. In particular, those birds with the steepest feedback functions responded at rates almost sufficient to drive reinforcement rate to zero. This is particularly striking because it is just these schedules that should have allowed for the easiest discrimination of a correlation between a decrease in response rate and an increase in reinforcement rate.

According to an equilibrium analysis, the adaptiveness of behavior is revealed when, constrained by a schedule, an organism acts so that both instrumental behavior and contingent behavior are changed from baseline as little as possible. Performances on the present schedules are anything but adaptive in

Fig. 1. Response rates and reinforcement rates for each of the 9 birds in Experiment 1. Maximization of reinforcement rate occurs in the vicinity of 2 responses per min. Left column: FR 20 subtracted from VI schedule. Middle: FR 40 subtracted. Right: FR 60 subtracted.

that sense. A similar conclusion applies to analyses in terms of minimization of deviations from a free-behavior point, and in terms of maximization of value: Neither approach appears to make sense of these data. On the other hand, these results are consistent with the traditional assumption that the presentation of reinforcement strengthens immediately preceding behavior (discussed further below).

EXPERIMENT 2

Given the results of Experiment 1, it seems reasonable to ask how a bird would behave if confronted with two keys concurrently, each having a linear schedule with negative slope. In particular, if matching (Herrnstein, 1961, 1970) of relative responses to relative obtained reinforcers were to occur, without rate of reinforcement being maximized, an explanation of matching in terms of maximization (cf. Rachlin et al., 1981; Staddon & Motheral, 1978) would be brought into question.

Subjects

Six naive White Carneaux pigeons were used, three in each of two conditions. They were run at approximately 80% of their free-feeding weights.

Apparatus

Two standard two-key pigeon chambers were used, one for each condition. The first was 30 cm wide, 30 cm in length, and 32 cm high. Two pigeon keys, 1.9 cm in diameter, were located 13 cm apart on the front wall, 23 cm from the floor. A standard grain hopper was centered on the wall below the keys. A force of about 0.14 N was required to operate the keys. The left key was transilluminated with two 7-W green bulbs, the right with two 7-W red bulbs. The chamber was illuminated, except during reinforcement, with two 7-W white bulbs; during reinforcement only the hopper was illuminated. Responses produced audible feedback clicks. White noise and a fan masked extraneous noise. The experiment was controlled by a PDP-9T computer.

The second chamber was 30 cm wide, 30 cm in length, and 32 cm in height. Two standard pigeon keys, 1.9 cm in diameter, were 15 cm apart and 23 cm from the floor. A standard food hopper was centered below the keys. A force of about 0.14 N was required to operate the keys. The left key was transilluminated with white light from two 2-W 28-V bulbs; the right was transilluminated with green light. The chamber was illuminated with two 7-W white bulbs. Responses produced audible feedback clicks. During reinforcement, the hopper and house-lights were both lit. A PDP-9T computer controlled the experiment.

Procedure

In the first condition, three birds were exposed to concurrent schedules the feedback functions of which were linear with negative slopes and equal intercepts. Specifically, the schedules were concurrent linear VI 45-s schedules, from which FR schedules were subtracted. The VI schedules consisted of 20 intervals from the distribution of Fleshler and Hoffman (1962). Each bird was exposed to five schedules, in all of which the sum of the two fixed ratios was 80. The FR schedules used were 60 and 20, 30 and 50, 50 and 30, 20 and 60, and 40 and 40 (for the left and right keys, respectively). In the second condition (in which the second chamber was used), the same contingencies were in effect, except that the linear VI schedules were VI 60-s on the left and VI 30-s on the right. Thus, while the first condition involved equal intercepts (and thus similar maximum rates of reinforcement) for the concurrently available schedules, the second condition involved unequal intercepts.

At the end of each session the positions of the VI schedules, the FR schedules, and the stored surplus (or deficit) of reinforcements were printed out and entered at the beginning of the next day's session. Each session thus began where the schedules had finished the previous day.

A 3-s changeover delay (COD) was in effect; in addition, following reinforcement, 3 s had to elapse before a subsequent rein-

Table 2

Schedules and number of sessions for each bird in Experiment 2

Schedule	Subject		
	58	59	62
Conc VI 45-s VI 45-s			
FR 60, FR 20	20	21	20
FR 30, FR 50	24	31	21
FR 50, FR 30	24	25	28
FR 20, FR 60	23	23	27
FR 40, FR 40	29	24	28
	175	176	111
Conc VI 60-s VI 30-s			
FR 60, FR 20	23	24	24
FR 30, FR 50	21	20	22
FR 50, FR 30	28	28	27
FR 20, FR 60	28	27	25
FR 40, FR 40	28	30	28

forcer could be collected. Reinforcement consisted of 3-s access to mixed grain. Sessions terminated after 40 reinforcers or 35 min, whichever occurred first, and were run 7 days a week. Each condition was run for a minimum of 20 sessions, following which the

schedules were changed when relative response rates appeared stable. Table 2 lists the schedules and the number of sessions for each bird.

Figure 2 shows the results for each of the birds whose schedules had equal intercepts (the first condition). The data points falling on the schedule functions (solid lines) show rates of responding and reinforcement for each of the two keys, averaged over the last 5 days of each schedule. The points at the end of the dotted lines correspond to the sum of the two data points. To the extent that the first two points fall on the dotted lines, the data are in accord with matching; the dotted line plots a constant ratio (specifically, the overall ratio for those sessions) between responses and obtained reinforcers.

The data for the second condition (unequal intercepts) are shown in Figure 3. For both Figures 2 and 3, the continuous reinforcement (CRF) segment of the functions (which are shown in Figure 1) are not plotted, because the scale would force it too close to the ordinate.

Fig. 2. Response rates and reinforcement rates for each of the 3 birds in experiment 2 on schedules with equal intercepts. Maximization of reinforcement rate (not shown, due to scale) occurs in the vicinity of 2 responses per min. The data points at the end of the dotted lines are the sums of the points for the individual schedules; the extent to which those latter points fall on the dotted lines is a measure of the closeness to matching.

Fig. 3. Response rates and reinforcement rates for each of the 3 birds in Experiment 2 on schedules with unequal intercepts. The dotted lines were derived as for Fig. 2.

There are several conclusions that may be drawn from these data. Most evident is the fact that, as in Experiment 1, rate of reinforcement was not maximized. Both Experiments 1 and 2, then, appear inconsistent with an analysis in terms of equilibrium, minimization of distance from a free-behavior point, or maximization of value.

There is, however, a weaker version of these approaches that can also be tested against these data. Suppose that (for whatever reason) the contingent reinforcements constrained the birds to emit responses at some moderately high rate. Given that responses are being directed to two keys with unequal slopes (which includes four of the five schedules for each bird), it is possible to increase reinforcement rate by redirecting some of those responses from the key with the steeper slope to the key with the shallower slope. This follows because the increase in reinforcement rate on the first key will more than offset the decrease on the second key (due to the unequal slopes). This is a variant of the standard argument put forth in microeconomics that, if marginal utilities

are unequal, total utility can be increased by redistributing some income from an alternative with lower marginal utility (Mansfield, 1975).

Consider, for example, the first set of schedules for Bird 59 (Figure 2). On the schedule with steeper slope the data point lies above the dotted line (and hence, on the schedule with shallower slope, it lies below it). Because matching is equivalent to the data points lying on the dotted line, in this case it might be concluded that matching was being violated to some extent, while a weak form of maximization was being exhibited.

However, perusal of all the data shows that there is no systematic departure from matching in a direction consistent with this weak form of maximization. For example, the second set of schedules for Bird 59 shows just the opposite effect: More responses occurred on the schedule with a steeper slope, relative to matching, than occurred on the schedule with a shallower slope. Overall there appears to be no net tendency for responses to be displaced from the schedule with a steeper slope to the schedule with a

shallower slope, relative to matching (the dotted line).

It is also possible to test matching (of the ratio of responses to the corresponding ratio of obtained reinforcements) against these data. Although the dotted line must fall on or between the two data points (i.e., both data points cannot, logically, fall to the side of the dotted line), it is logically possible for these data points to be near to or far from the dotted line. It is evident from both Figures 2 and 3 that the former consistently holds: The data points tend to either lie on, or close to, the dotted line. The degree to which matching occurred is shown by Figure 4, in which the log ratio of responses is plotted as a function of the log ratio of obtained reinforcers. Least squares linear fits to the data are also shown in the Figure (Table 3 shows the slopes, intercepts, and percentages of variance accounted for). There is more noise in

Figure 4 than one finds with more common procedures, but this is to be expected, given a procedure in which reinforcement rates on both keys vary as response rates vary. What is more apparent, then, is that the data are reasonably orderly with respect to matching, while simultaneously violating maximization (and similar approaches), both in their original form and in a weaker form.

It is worth considering a number of cases in which experiments designed to discriminate between matching and maximization have been criticized by advocates of maximization, to see how such criticisms relate to the current experiments. Mazur (1981), for example, ran a procedure in which reinforcement was programmed on the basis of interdependent VI schedules. When blackouts were substituted for some proportion of reinforcements on one side, the distribution of behavior shifted toward the other side,

Fig. 4. Log ratio of responses as a function of log ratio of obtained reinforcers for Experiment 2. Top: birds with equal intercepts. Bottom: birds with unequal intercepts.

Table 3

Slopes, intercepts, and percentages of variance accounted for (r^2) in Experiment 2

<i>Bird</i>	<i>Slope</i>	<i>Intercept</i>	<i>r²</i>
58	.65	-.16	.92
59	1.29	.09	.36
62	.53	.05	.96
175	.98	-.03	.99
176	.96	-.08	.83
111	.44	.13	.94

which in turn lowered overall obtained rate of reinforcement below what could have actually been obtained. Staddon and Hinson (1983) have criticized this procedure in part because the pigeons may have been constrained by an inability to detect the contingencies at work. On the face of it, it would seem that the present experiments are immune to this particular criticism, inasmuch as an ability to detect the slope of schedule functions has been assumed by maximization theorists themselves.

Herrnstein and Heyman (1979) reported matching, as opposed to maximization, on a concurrent VI VR experiment. This has been criticized by Green, Kagel, and Battalio (1982), who say a bias should be expected for the VI side because of leisure being a commodity, "one that is highly substitutable for food" (p. 419). However, if both leisure and food are commodities, one should expect a package consisting of much leisure and much food to be highly preferred over one consisting of little leisure and little food, exactly the opposite of the pattern of results found here.

This same experiment has been criticized by Ziriaux and Silberberg (1984), who report that the matching result found by Herrnstein and Heyman may result primarily from a VR feedback function. That is, as more behavior is directed to the VR side, more reinforcers will be received there, so a matching relation may obtain largely through procedural constraint. With respect to the present concurrent schedules, however, as more responses are directed to a key, fewer reinforcers will be received there. The conjunction of Experiment 2 here and

that of Herrnstein and Heyman suggests that matching holds whether or not an increase in responses directed to a key increases the number of reinforcers received there.

GENERAL DISCUSSION

Equilibrium analyses, minimum-deviation analyses, and maximization-of-value analyses were all developed on the basis of data collected on schedules with positive slopes within the coordinates of reinforcement rate as a function of response rate. For all of those analyses, a positive slope is an integral part of the explanation of why responding is maintained as it is on interval and ratio schedules. In addition, the explanation of matching in terms of maximization of value depends in an integral way on rate of reinforcement increasing as matching is approached. The fact that responding is well maintained on single-key linear VI schedules (Vaughan, 1976), and that matching, or slight undermatching, is seen on concurrent linear VI schedules (Herrnstein & Vaughan, 1980; Vaughan, 1982) are both inconsistent with those analyses. These results, as well as those reported here, suggest that pigeons, at least, may in fact not be sensitive to the slopes of the feedback functions.

We will not attempt here a systematic explanation of what variables appear to govern pigeons' response rates on various single-key and concurrent-key schedules. What does seem clear, however, is that a strengthening analysis of reinforcement can make some sense of these data. For example, on the single-key schedules, given low rates of responding and high rates of reinforcement, it seems plausible to assume that reinforcement simply increases the tendency to respond, independent of the fact that the increase in response rate drives down the rate of reinforcement. Similarly, on schedules with flat slopes, a strengthening analysis of reinforcement would imply that response rates should be similar to what are found on normal VI schedules, as is the case. It may be that a strengthening analysis could also

account for the higher response rates on VR, as compared to VI schedules with equal obtained rates of reinforcement, on the basis of the differences in the distributions of reinforced interresponse times. Thus, although such an analysis remains to be worked out in coherent detail, the present data strongly suggest that alternatives to a strengthening account of reinforcement that have been put forth cannot be relied on to make correct predictions with regard to previously untried schedules.

There may, however, still be a role for such analyses. If, for example, most species evolved in environments in which there tended to be a positive correlation between response rate and reinforcement rate, then a process of strengthening could have evolved because it tended, on the whole, to maximize value (or fitness). Thus, confining one's study of animal behavior to situations in which value is maximized may help one to understand the likely conditions under which the species evolved. On the other hand, if one is after the mechanisms that in fact govern behavior, it will probably be necessary to expose animals to situations unlike those previously encountered in their evolutionary history.

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