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CHOICE IN TRANSITION: A COMPARISON OF MELIORATION AND THE KINETIC MODEL

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Transition-state choice behavior of pigeons was examined in two experiments designed to test predictions of melioration and the kinetic model. Both experiments began with an initial training condition during which subjects were maintained on concurrent variable-interval schedules. In Experiment 1, subjects were then exposed to concurrent variable-ratio schedules, whereas in Experiment 2, subjects were then exposed to concurrent extinction. Contrary to the predictions of melioration, but consistent with the kinetic model, acquisition of preference on concurrent variable-ratio schedules followed a negatively accelerated logistic trajectory, and preference remained stable in concurrent extinction. Predictions made by the kinetic model concerning rates of switching between alternatives were also supported.

Key words: kinetic model, melioration, matching law, choice, transition-state behavior, concurrent schedules, key peck, pigeons

The behavior of organisms on probabilistic concurrent schedules of reinforcement is well described by the matching law (Herrnstein, 1970; for a review see de Villiers, 1977). For time allocation, the matching law may be written as

$$T_1/T_2 = R_1/R_2 \qquad (1)$$

(Baum & Rachlin, 1969), where T_1 and T_2 are the cumulative durations of two behaviors and R_1 and R_2 are the obtained rates of reinforcement for those behaviors. The purpose of the present endeavor is to compare two theories of the process that gives rise to matching. One theory, melioration, describes a process whereby the organism adjusts its preference so as to equalize local rates of reinforcement (Herrnstein, 1982; Herrnstein & Vaughan, 1980; Vaughan, 1981; Vaughan & Herrnstein, 1987). The other theory, the kinetic model, describes an equilibration process formally similar to the kinetics of chemical reactions (Myerson & Miezin, 1980; Staddon, 1977). Both theories make identical steady-state predictions (i.e., matching) but may be distinguished by their transition-state predictions for certain simple experimental situations.

According to the melioration theory, organisms allocate behavior based on the difference, D, between local reinforcement rates:

$$dP/dt = \mathrm{f}(D) = \mathrm{f}(N_1/T_1 - N_2/T_2), \qquad (2)$$

where P is preference for the alternative whose current local reinforcement rate is N_1/T_1, and $\mathrm{f}(D)$ is any increasing function such that $\mathrm{f}(0) = 0$. At equilibrium, $N_1/T_1 - N_2/T_2 = 0$, and rearranging yields $T_1/T_2 = N_1/N_2$. Dividing both the numerator and denominator of the right-hand fraction by $T_1 + T_2$ converts this fraction to the ratio of the overall reinforcement rates which equals (matches) the time ratio (Equation 1).

According to the kinetic model, each reinforcement on one schedule decreases the rate of switching to the alternative by some proportion, k, and the sum of the local rates of switching back and forth is a constant, c. This may be expressed as

$$d\lambda/dt = k{*}R_2{*}(c - \lambda) - k{*}R_1{*}\lambda, \qquad (3)$$

where λ is the local rate of switching from the alternative reinforced at rate R_1 to the alternative reinforced at rate R_2, and $c - \lambda$ is the local rate of switching back again. Local switching rate is defined as the number of switches from a schedule divided by the time spent on that schedule. Thus the local switching rates λ and $c - \lambda$ equal n/T_1 and n/T_2, respectively, where n is the number of switches

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(on the average, the number of switches from one alternative to the other should equal the number of switches back the other way). At equilibrium, $k{\bullet}R_2{\bullet}(c - \lambda) - k{\bullet}R_1{\bullet}\lambda = 0$, and rearranging yields $(c - \lambda)/\lambda = k{\bullet}R_1/k{\bullet}R_2$. Substituting n/T_1 and n/T_2 for λ and $c - \lambda$, and cancelling n and k, yields Equation 1.

A molar version of the kinetic model that describes changes in preference (i.e., relative response or time allocation) may be derived from the molecular version described above (Myerson & Miezin, 1980). The molar version of the model may be expressed as

$$dP/dt = k{\bullet}R_1{\bullet}(1 - P) - k{\bullet}R_2{\bullet}P, \qquad (4)$$

where P is preference for the alternative whose overall reinforcement rate is R_1 and $1 - P$ is preference for the other alternative. When feedback functions for the appropriate schedule types are substituted into the preceding equation, the kinetic model predicts the specific forms of the trajectories describing changes in preference following changes in schedule types and schedule values. For example, the model predicts negative exponential trajectories and logistic trajectories on concurrent variable-interval (CONC VI VI) and concurrent variable-ratio (CONC VR VR) schedules, respectively (Myerson & Miezin, 1980).

The melioration process also leads to steady-state matching, but the precise form of the trajectory cannot in general be determined. Herrnstein and Vaughan (1980) did not specify the functional relation between the size of a change in preference and the size of the difference in local reinforcement rates. Without knowing this relation, f(D), it is impossible to derive transition-state predictions for most situations (e.g., CONC VI VI). For CONC VR VR, however, a precise prediction of the preference trajectory can be derived, and therefore a direct comparison between melioration and the kinetic model is possible. Experiment 1 of the present study was conducted to test the CONC VR VR predictions of the two theories. A more general form of melioration, from which no transition-state predictions can be derived, has been recently proposed by Vaughan (1985); this form will be considered below in the General Discussion.

A comparison can also be made between predictions of behavior during concurrent extinction of two responses (CONC EXT EXT) following training on concurrent reinforcement schedules. Although neither the kinetic model nor melioration make predictions concerning the absolute levels of responding in CONC EXT EXT, they do make different predictions concerning the relative rates of responding. Experiment 2 of the present study was conducted to test the CONC EXT EXT predictions of melioration and the kinetic model.

EXPERIMENT 1

The melioration prediction for acquisition of preference on CONC VR VR is derived by substituting the VR feedback function (Baum, 1973) into Equation 2. The number of reinforcers obtained on a VR is equal to the number of responses multiplied by the probability that a response will be reinforced, ϕ, which is the reciprocal of the schedule value. On concurrent schedules, the number of responses for a given alternative equals the local response rate, r, multiplied by the time, T, allocated to that alternative. Thus the VR feedback function is $N = r{\bullet}\phi{\bullet}T$. For example, on a VR 50 the value of ϕ is 1/50 or .02. If a subject allocates a total of 20 min to this schedule during which its response rate was 100 per minute it would receive approximately 100•.02•20 or 40 reinforcers. Substituting VR feedback functions for N_1 and N_2 into Equation 2 yields

$$dP/dt = \mathrm{f}(D) = \mathrm{f}((r_1{\bullet}\phi_1{\bullet}T_1)/T_1 - (r_2{\bullet}\phi_2{\bullet}T_2)/T_2). \qquad (5)$$

Cancelling time values reveals that

$$D = r_1{\bullet}\phi_1 - r_2{\bullet}\phi_2.$$

Local rates of responding are relatively independent of preference (Catania, 1963; Herrnstein, 1961, 1970; for a review see McSweeney, Melville, Buck, & Whipple, 1983), and thus r_1 and r_2 are effectively constants. When the schedule values ϕ_1 and ϕ_2 are held constant, D is the difference of the products of constants and is thus a constant itself. Because any function of a constant has a constant value, the rate of change of preference, dP/dt, must be a constant. Therefore, the solution for Equation 3 is linear in form, that is, melioration predicts a linear trajectory for transition-state preference on CONC VR VR.

This prediction made by melioration differs from the kinetic model's prediction. When VR feedback functions are substituted into Equa-

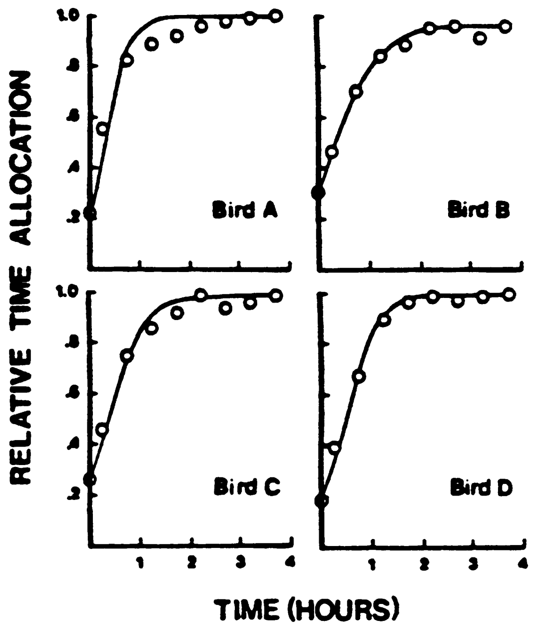

Fig. 1. Preference acquisition on CONC VR VR, in terms of relative time allocation as a function of hours. Values plotted at time zero represent the means of the last 5 days on CONC VI VI.

tion 4, the solution to this differential equation is the logistic function

$$P(t) = P(0)\frac{1 + C}{1 + Ce^{kr(\phi_1-\phi_2)t}}$$

where $P(0)$ is the initial preference and C is the ratio of that preference to initial preference for the other alternative (Myerson & Miezin, 1980). This trajectory is negatively accelerated as it approaches asymptote.

At the molecular level, the kinetic model predicts that the overall switching rate should remain proportional to the product of the preferences for both alternatives, $P \cdot (1 - P)$, in both transition and steady states (Myerson & Miezin, 1980). Thus the kinetic model not only predicts a specific form for molar preference acquisition, but it also predicts a specific form for changes in the rate of switching between concurrent alternatives during the acquisition of preference.

METHOD

Subjects

Four adult Roller pigeons served as subjects in this experiment. Supplemental feeding was used when necessary to maintain them at 80% of their free-feeding weights. All four birds had previous experience with two-key concurrent schedules.

Apparatus

Two standard two-key operant conditioning chambers for pigeons, manufactured by Coulbourn Instruments, were used. During experimental sessions, the left key was transilluminated green and the right key was transilluminated with a vertical line that appeared on a dark background. Whenever the birds were in the experimental chamber, noise from an exhaust fan fitted to the chamber provided auditory masking and a houselight provided general illumination. Sessions were controlled via programs developed in our laboratory (for a description see Hale, Myerson, & Miezin, 1982) and implemented on a Data General Nova 4/C® computer located in an adjacent room.

Procedure

All four birds were initially trained on CONC VI VI schedules of reinforcement until no trend was observed in both relative response and time allocations for 5 consecutive days. Birds A and B were on CONC VI 45-s VI 180-s schedules for 22 and 33 days, respectively, and Birds C and D were on CONC VI 22.5-s VI 90-s schedules for 10 and 34 days, respectively. Once performance was stable, all birds were then exposed to CONC VR 135 VR 45, with the previously less preferred key now associated with the higher reinforcement probability. They were maintained on CONC VR VR for 8 days, at which time preference was almost exclusive for the richer VR schedule. Reinforcement consisted of 3-s access to mixed grain. Experimental sessions were conducted daily and lasted 30 min.

RESULTS AND DISCUSSION

In the CONC VI VI training condition, all four birds showed slight undermatching of time allocation (mean deviation from relative reinforcement = −.058). Relative responding showed more pronounced undermatching (mean deviation = −.157). In the CONC VR VR condition, preference for the key associated with the richer VR showed a negatively accelerated increase over time for all four birds. As may be seen in Figure 1, relative time allocation was very well described by a logistic function for three of the four birds (Table 1);

Table 1

Parameters for best fitting logistic (kinetic model) and linear (melioration) functions.

	Relative time allocation				Relative response allocation			
	Logistic		Linear		Logistic		Linear	
Bird	k	% VAR	Slope	% VAR	k	% VAR	Slope	% VAR
A	0.0357	78.7	0.859	74.0	0.0342	68.3	0.873	65.4
B	0.0156	97.9	0.457	93.0	0.0190	95.4	0.615	91.9
C	0.0308	95.3	0.535	87.8	0.0286	94.4	0.516	87.5
D	0.0195	98.5	0.592	97.7	0.0214	95.8	0.669	91.8

for Bird A, however, relative time allocation showed an even more negatively accelerated (i.e., even less linear) trajectory than a logistic function.

Similar results were obtained for relative response allocation (Figure 2). In fitting both the logistic function predicted by the kinetic model and the linear function predicted by melioration to the data, the initial value was assumed to be the mean of the last 5 days of the preceding CONC VI VI condition and the asymptotic value was assumed to be the value obtained on the last day of the CONC VR VR condition. Thus both functions were fit with only one free parameter. For the kinetic model, the free parameter was k. For melioration, the free parameter was the slope of the line from the initial preference value to the horizontal line through the asymptotic preference value. As may be seen in Figures 1 and 2 and Table 1, these results clearly support a logistic trajectory as predicted by the kinetic model rather than a linear trajectory as predicted by melioration.

Moreover, the estimated values for k ($M = 0.025$) were in good agreement with those obtained in previous experiments with CONC VI VI schedules. Myerson and Miezin (1980) analyzed the small amount of transition-state data from operant choice experiments available in the literature. This included data reported by Catania (1969) for two birds exposed to a two-key procedure and 100-min daily sessions; k was estimated to be 0.030 for transitions to exclusive preference when reinforcement for responses on one of the keys was discontinued. Myerson and Miezin also analyzed data reported by Killeen (1972) for one of two birds on a changeover-key procedure; k was estimated to be 0.022 for this bird's transitions from preference for one key color to preference for the other color (the other bird in the Killeen study acquired new preferences too rapidly to permit estimation of the value of k). Killeen conducted two sessions daily with an average duration of 17 to 18 min. Given the procedural differences (i.e., VI VI and VR VR schedules, two-key and changeover-key procedures, transitions to exclusive as well as nonexclusive preference, different session durations as well as differences in the number of sessions per day) the agreement between the estimated k values for the present experiment and the Catania and Killeen studies is impressive.

In the kinetic model, the value of k measures the proportion of preference that a single reinforcer transfers to a reinforced response from

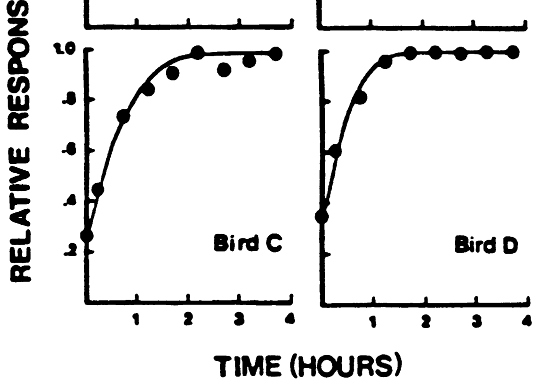

Fig. 2. Preference acquisition on CONC VR VR, in terms of relative response allocation as a function of hours. Values plotted at time zero represent the means of the last 5 days on CONC VI VI.

the alternative response (Myerson & Miezin, 1980). Thus these results indicate that despite the differences in the steady-state behavior maintained by concurrent-interval and concurrent-ratio schedules, the size of the effect of a single reinforcer is the same with both procedures. One of the major advantages of the kinetic model is that the *k* parameter provides a measure of the actual strengthening effect of reinforcer delivery. The present example demonstrates that the same reinforcer magnitude (3-s access to mixed grain) produces about the same degree of strengthening despite differences in procedure, and thus strongly supports this interpretation of the *k* parameter in the kinetic model.

Switching rates for the 8 days of the CONC VR VR condition are plotted as a function of preference (relative time allocation) in Figure 3. As may be seen, the relationship is well described by the inverted U-shaped function predicted by the kinetic model:

$$S/S_{\max} = 4 \cdot P \cdot (1 - P)$$

where S is the overall switching rate and $S_{\max}$ is the theoretical maximum (i.e., the switching rate predicted for a preference of 0.5). This theoretical function is derived from the assumption that the amount of attraction in a choice situation, measured as the sum of the local switching rates, remains constant despite changes in preference as long as overall reinforcement rate does not change appreciably. The value of $S_{\max}$ may be calculated as half of the mean sum of the local switching rates (Myerson & Miezin, 1980). In the present case, for each bird the mean sum for the first 4 days of the CONC VR VR condition was used. The fit of the theoretical curve to the present data involved no free parameters; one empirical constant ($S_{\max}$) was used to normalize the data.

The results presented in Figure 3 may seem unremarkable if one does not consider the alternatives. Although exclusive preference must accompany a switching rate of zero, and it is reasonable to assume that the maximum rate will occur when preference (i.e., relative time allocation) equals one half, the function relating switching rate to preference could, in principle, take any of a variety of forms. For example, switching could decrease in a linear or negatively accelerated fashion, rather than the positively accelerated manner predicted by the kinetic model (Myerson & Miezin, 1980). Moreover, the relation between switching and asymptotic preference could, in principle, be different from the relation between switching and preference in transition, and the relation might also differ depending on the types of concurrent reinforcement schedules.

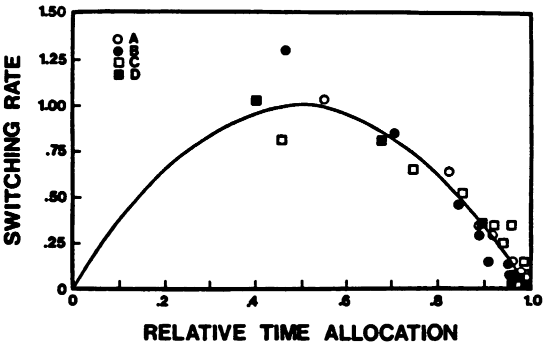

Fig. 3. Normalized switching rate as a function of relative time allocation. For each bird, overall switching rate has been normalized by dividing by the mean sum of the local switching rates for the first 4 days of CONC VR VR.

As revealed by Figure 3, however, switching is related to preference in the transition state on CONC VR VR in precisely the manner predicted by the kinetic model. The same equation, with no free parameters, also describes the relation between switching and preference on CONC VI VI and CONC VI VR in both steady and transition states (Myerson & Hale, 1984; Myerson & Miezin, 1980), and thus represents an important quantitative generalization about operant choice behavior, notable both for its parsimony and its power.

The present results clearly support both predictions made by the kinetic model, that is, the negatively accelerated (logistic) trajectory of preference on CONC VR VR as well as the form of the switching rate function in the transition state. In addition, the results are consistent with the kinetic model's prediction that only the current reinforcement rates affect preference, and that therefore the speeds of transitions are not affected by rates of reinforcement in preceding conditions. Two of the birds, A and B, were trained with CONC VI 45-s VI 180-s schedules, whereas the other two, C and D, were trained on CONC VI 22.5-s VI 90-s schedules on which reinforcement was available at twice the rate. The values of the *k* parameters (mean for Birds A and

B = 0.0256 and mean for Birds C and D = 0.0254) indicate that despite the differences in the overall reinforcement rates of the preceding training conditions, both pairs of birds changed their preferences at the same speed.

EXPERIMENT 2

Although neither melioration nor the kinetic model makes predictions concerning absolute rates of responding during CONC EXT EXT, predictions concerning preference (i.e., the distribution of behavior) during CONC EXT EXT can be derived from both theories. Specifically, melioration predicts that preference will become less extreme as CONC EXT EXT proceeds, whereas the kinetic model predicts that preference will not change in CONC EXT EXT.

To derive melioration's predictions for CONC EXT EXT, one must consider how organisms "calculate" local reinforcement rates. Prior to CONC EXT EXT, preference will be stable if local reinforcement rates are equal (i.e., when matching occurs). For example, if a subject spent 2 of every 3 min responding on a key with an overall rate of 2/3 reinforcements per minute (VI 90 s) and spent 1 of every 3 min on a key with an overall rate of 1/3 reinforcements per minute (VI 180 s), then both local reinforcement rates would be one per minute. (In 3 min of session time, two reinforcers would be earned in 2 min of "local" time on the richer schedule and one reinforcer would be earned in 1 min of "local" time on the leaner schedule.)

If CONC EXT EXT began at this point, local reinforcement rates would quickly become unequal. Herrnstein and Vaughan (1980) suggested that organisms calculate a schedule's local reinforcement rate based on the number of reinforcements obtained within some time period spent on that schedule, the "memory window." To continue with our example, if during the first 3 min of CONC EXT EXT, the subject spent 2 min on the key previously associated with the richer schedule and 1 min on the previously leaner key, then as current experience replaced past experience in "memory," the subject would "forget" two richer key reinforcers but only one leaner key reinforcer. Therefore, the reinforcement rate associated with the previously leaner key would now exceed that associated with the richer key. Thus melioration predicts that preference would shift in the direction of the formerly leaner key. Using a different derivation, Prelec (1984) has also demonstrated that melioration predicts a shift in preference in this direction.

The kinetic model makes a different prediction regarding preference during extinction: Each reinforcement associated with a specific source appropriates to that source a fixed proportion of preference previously allocated to alternative sources. Therefore during CONC EXT EXT (i.e., in the absence of any reinforcement) preference should remain relatively unchanged, and any changes that do occur should be unsystematic.

METHOD

Subjects and Apparatus

The same four adult Roller pigeons used in Experiment 1 served in this experiment. Supplemental feeding was used when necessary to maintain them at 80% of their free-feeding weights. The apparatus was the same as that used in Experiment 1.

Procedure

All four birds were trained on CONC VI 90-s VI 180-s schedules until no trend was observed in both relative response and time allocation for 5 consecutive days. Prior to this condition, all four birds had spent 1 month on a CONC VI VR reinforcement schedule that provided comparable relative reinforcement rates, and stable preference on CONC VI VI was observed after only 6 to 8 days. For Birds A and C, the richer schedule was associated with the right key. For Birds B and D, the richer schedule was associated with the left key. Once preference was stable, reinforcement was discontinued for both responses. Extinction sessions were conducted until responding had virtually ceased on both keys. Birds A and B were exposed to six sessions of extinction, whereas Birds C and D were exposed to 12 sessions. During CONC VI VI training, reinforcement consisted of 3-s access to mixed grain. Experimental sessions were conducted daily and lasted 30 min.

RESULTS AND DISCUSSION

In the CONC VI VI training condition, mean relative time and mean relative responses were roughly equal to mean relative reinforce-

Table 2

Data summed across last five CONC VI VI sessions and summed across all CONC EXT EXT sessions. Proportions (rich/total) are given in parentheses.

	CONC VI VI						CONC EXT EXT			
	Reinforcers		Responses		Time (s)		Responses		Time (s)	
Bird	Rich	Lean	Rich	Lean	Rich	Lean	Rich	Lean	Rich	Lean
A	95 (.683)	44	13,178 (.607)	8,538	5,938 (.692)	2,645	3,822 (.695)	1,675	9,276 (.859)	1,524
B	98 (.676)	47	9,674 (.588)	6,790	6,004 (.701)	2,561	2,459 (.509)	2,370	8,606 (.797)	2,194
C	93 (.655)	49	10,456 (.658)	5,428	6,371 (.743)	2,203	9,134 (.689)	4,128	18,943 (.877)	2,656
D	90 (.662)	46	11,765 (.580)	8,354	6,352 (.739)	2,240	11,934 (.650)	6,439	17,088 (.791)	4,512

ments (Table 2) although slight undermatching occurred for responses and slight overmatching occurred for time. (All relative measures, i.e., reinforcements, responses, and time, are reported for the four birds in terms of the richer schedule divided by the total.) Responding on both keys decreased to minimal levels in CONC EXT EXT. With the exception of 1 day each for Birds B and D, more responses were always emitted on the key previously associated with the higher rate of reinforcement (Figure 4). When the allocation of behavior in CONC EXT EXT is compared with that in the preceding condition, it may be seen that although relative time became more extreme for all four birds, there was no consistent change in relative responses (Table 2).

Of the two measures, response allocation may provide a more reliable measure of preference in CONC EXT EXT. During CONC EXT EXT, time is increasingly allocated to nonresponding. Therefore, if pauses occur primarily during bouts of responding on one alternative, then relative time will exaggerate preference for that alternative (Baum, 1979). Thus, in CONC EXT EXT, response allocation may provide the best measure of time actually spent responding on the two alternatives.

Figure 5 shows the relative allocation of responses as a function of sessions in the last 5 days of CONC VI VI and the subsequent extinction of concurrent responding. Although preference measured as relative responding became less extreme for one subject (Bird B) and more extreme for another subject (Bird A), for the 2 subjects who extinguished most slowly (Birds C and D), preference did not change systematically from baseline levels.

Because responding decreases during extinction, analyzing behavior as a function of time or sessions may not be the best way to look at the stability or instability of preference. Each successive session in CONC EXT EXT usually represents a smaller sample of behavior than the previous session, and thus behavior may appear to become more variable over time simply as a result of the diminishing sample sizes. Because of these considerations, a

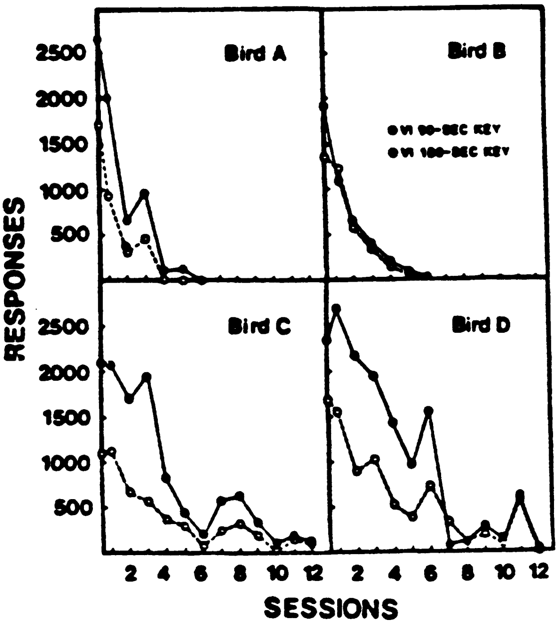

Fig. 4. Responding in CONC EXT EXT following training on CONC VI 90-s VI 180-s schedules. Values plotted at time zero represent the means for the last 5 days of CONC VI VI.

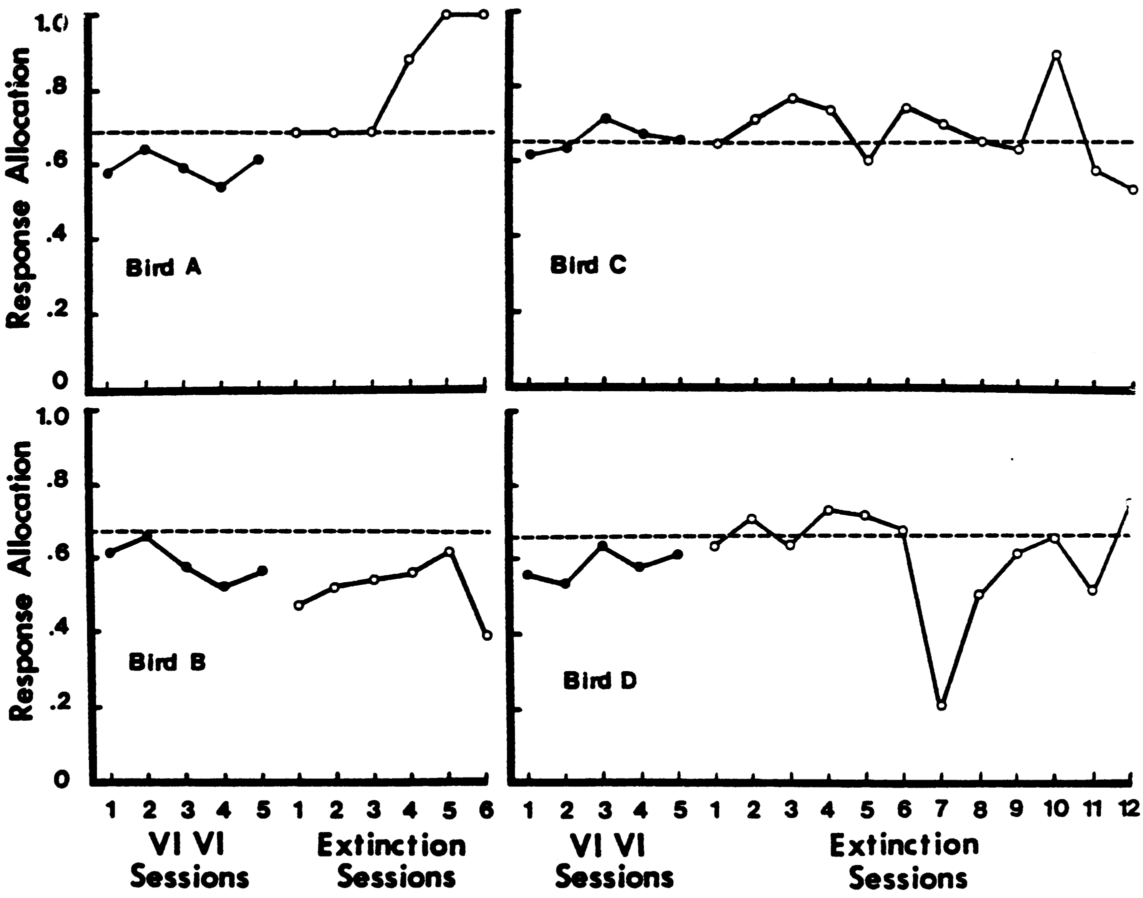

Fig. 5. Relative response allocation as a function of sessions. The dotted line represents the mean relative reinforcement for the last 5 days of CONC VI VI.

better way to look at the stability of preference in CONC EXT EXT may be to look at the relative numbers of responses in successive behavior samples of equal size. The results of such an analysis are shown in Figure 6, in which response preference is shown for successive bins of 1,000 responses. Preference was relatively stable throughout CONC EXT EXT; this may be seen most clearly in the cases of Birds C and D, the two birds who took the longest to extinguish. Not only did relative responding not change systematically during CONC EXT EXT, it closely matched the relative reinforcement rates from the previous CONC VI VI condition. Thus the present results strongly support the kinetic model.

GENERAL DISCUSSION

In Experiment 1, acquisition of preference on CONC VR VR followed a negatively accelerated (logistic) trajectory rather than the linear trajectory predicted by melioration. Where the trajectory departed from the logistic form predicted by the kinetic model (see Bird A, Figures 1 and 2), it was even more negatively accelerated (i.e., less linear) thus giving no support to melioration. In Experiment 2, relative responding remained approximately constant on CONC EXT EXT, whereas relative time allocation became more extreme. Again, the results are in direct contradiction to melioration, which predicts that preference should become less extreme in CONC EXT EXT. The kinetic model, on the other hand, predicts no change in preference. This prediction is supported by the relative response data which, it has been argued above, constitute the more appropriate measure of preference in CONC EXT EXT. Taken together, the results of the present two experiments support the kinetic model over melioration.

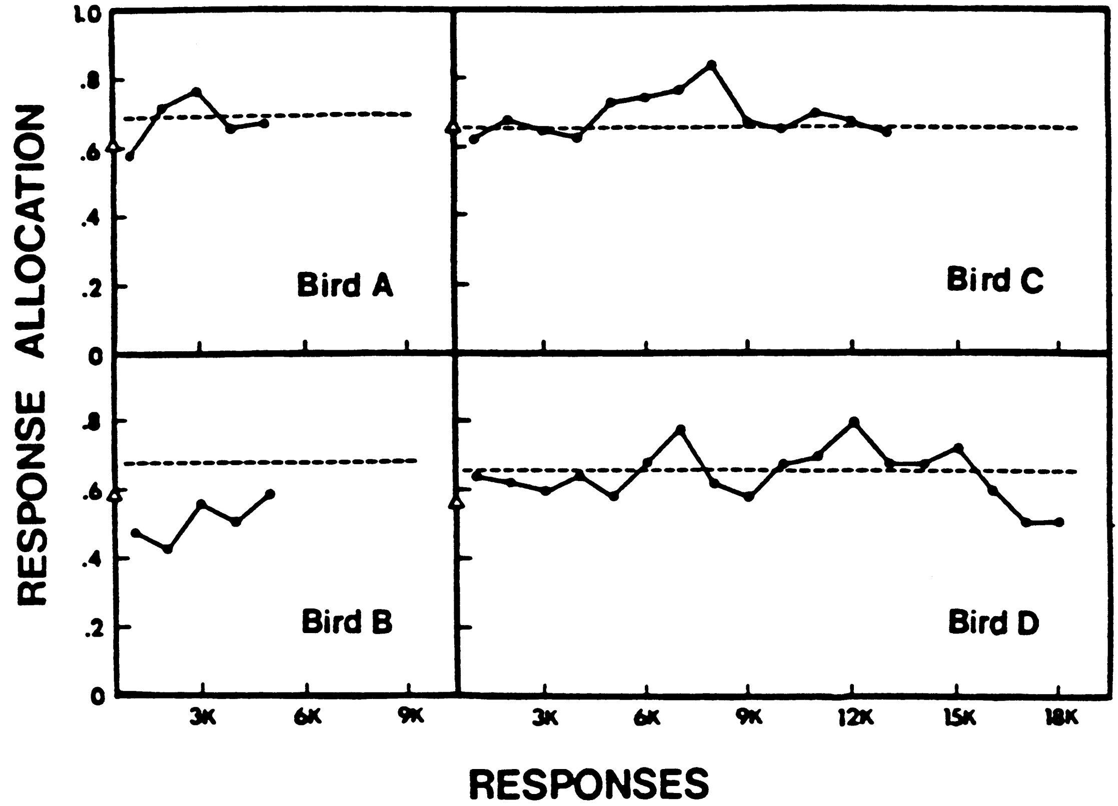

Fig. 6. Relative response allocation as a function of responses during CONC EXT EXT. Each point represents the mean response allocation for successive blocks of 1,000 responses. The dotted line represents the mean relative reinforcement for the last 5 days of CONC VI VI. The open triangle represents the mean relative response allocation for the last 5 days of CONC VI VI.

The kinetic model is closely related mathematically to a number of other models of choice, all of which have their roots in the earlier linear models of Bush and Mosteller (1951) and Estes (1950). Recent descendants of the linear models (e.g., see Kacelnik, Krebs, & Ens, 1987) may share with the kinetic model the predictions of a logistic form for the preference trajectory. However, the kinetic model is unique among these theories in that it integrates predictions at both the molar and molecular levels of both steady- and transition-state behavior on various concurrent reinforcement schedules, that is, CONC VI VI (Myerson & Miezin, 1980) and CONC VI VR (Myerson & Hale, 1984). The present results indicate that the kinetic model's predictions for transition-state switching behavior are also accurate for CONC VR VR.

Additional support for the application of the kinetic model to CONC EXT EXT is found in Skinner (1950). Referring to an unpublished study, Skinner reported that when a pigeon's pecking on two keys was extinguished following CONC VI VI, the ratio of left key pecks to right key pecks did not change during CONC EXT EXT. Nevin and Shettleworth (unpublished research cited in Nevin, 1979), however, obtained variable results with extinction following CONC VI VI. Although we are not aware of any previously published studies of extinction following CONC VI VI, the results of one unpublished study (Nevin and Shettleworth's) are equivocal, whereas the results of the other unpublished study (Skinner's) are in clear agreement with the present results and thus support the kinetic model over melioration.

Recently, Vaughan (1985) has proposed a generalization of melioration. In its original formulation, however, melioration was already quite general. Although specifying that the change in preference was an increasing function of the difference in local reinforcement rates (with f(0) = 0), melioration did not specify anything further about the form of that function. As mentioned above, this makes it impossible to derive transition-state predictions for CONC VI VI, although predictions for CONC VR VR were derived and tested. In the general (Vaughan, 1985) formulation of melioration, not only is the form of the function of the difference in local reinforcement rates unspecified, but in addition, that unspecified function may itself change in form in unspecified ways under unspecified conditions.

It has been claimed that melioration differs from alternative theories such as maximization in that the former explicitly specifies a dynamic process (Vaughan & Herrnstein, 1987). The generalized formulation of melioration, however, is no longer explicit or specific enough to predict, or be disproved by, any transition-state data. This limitation would not matter if transition-state preference was too variable to predict. As the present results illustrate, however, choice behavior is as predictable in transition as it is at equilibrium.

It should also be noted that the original formulation of melioration (Herrnstein & Vaughan, 1980) may correctly predict transition-state behavior on concurrent schedules when subjects are presented with choice trials as opposed to free-operant choice procedures. Nevin (1969) reported that following matching of choice proportions to reinforcement proportions, preference approached indifference in extinction (as predicted by melioration) when discrete trials were employed.

Thus the present results suggest that different rules may govern transition-state behavior in free-operant and discrete-trials choice situations. That is, preference remains relatively unchanged in extinction following concurrent reinforcement when preference is measured using free-operant procedures but approaches indifference on discrete-trials procedures. Such a conclusion would not be inconsistent with the kinetic model, which describes the effects of reinforcement on switching between concurrent schedules (Myerson & Miezin, 1980). Behavior in discrete-trials situations does not involve switching in the same sense. Organisms in such situations do not go directly from responding on one schedule to responding, with possible reinforcement, on another schedule. Instead, responding on alternatives is always separated by a discriminably different intertrial period in which responding is not reinforced. It seems likely that, in the absence of switching that is controlled by overall reinforcement rates, the relevant dependent variable may become probability of responding, which in turn may be controlled by local reinforcement rates.

Although the preceding discussion focused on choice behavior in transition, the results of an important experiment by Newby (1980) raise questions concerning the melioration interpretation of steady-state matching. Newby first exposed pigeons to CONC VI VI schedules using a changeover-key procedure (Findley, 1958) and obtained approximate matching. He then modified the procedure so that the duration of visits to one alternative was controlled by the subject and the duration of visits to the second alternative was controlled by the experimenter. Newby manipulated the durations of visits to the latter alternative making them twice or half the duration chosen by the subject in the regular CONC VI VI condition. Increasing the experimenter-controlled visit duration over the subject-determined duration substantially decreased the local rate of reinforcement for that alternative and, according to melioration, should have caused subjects to increase the duration of visits to the other alternative. Likewise, decreasing the experimenter-controlled visit duration substantially increased the local reinforcement rate and should have caused subjects to decrease the duration of visits to the other alternative. Despite changes in local reinforcement rates of the experimenter-controlled alternative, subjects in Newby's experiment did not change the duration of visits to the other alternative.

Newby's (1980) results are clearly contrary to the melioration prediction, but they are consistent with the kinetic model. According to the kinetic model, switching rates are determined by the overall rates of reinforcement. Because overall reinforcement rates on CONC VI VI are relatively insensitive to changes in time allocation (Baum, 1981; Myerson & Miezin, 1980), Newby's manipulations had little effect on the overall reinforcement rates for either alternative. Therefore the kinetic model would not predict any change in that aspect of switching that was under the subject's control, and, in fact, no change was observed. Although Newby's study was addressed to a somewhat different issue, the data make an important contribution to the issue of the adequacy of melioration and of the kinetic model as theories of choice behavior and strongly support the latter theory.

Finally, it should be noted that most of the evidence supporting melioration is better construed as evidence against maximization (e.g., Boelens, 1984; Herrnstein & Vaughan, 1980; Mazur, 1981; Vaughan, 1981; Vaughan & Miller, 1984). That is, many of the studies that support melioration hinge on demonstrating that organisms will reach matching equilibria even if by so doing they decrease their overall rates of reinforcement. However, the kinetic model makes the same predictions as melioration in these situations, and therefore such evidence supports both theories. In contrast, the Newby (1980) experiment and the present two experiments focus on choice situations in which melioration and the kinetic model make different predictions. In these situations the evidence strongly supports the kinetic model over melioration.

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