DEVIATIONS FROM MATCHING AS A MEASURE OF PREFERENCE FOR ALTERNATIVES IN PIGEONS

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Preferences for larger or smaller formally defined response classes were investigated in a concurrent schedule procedure. Twelve pigeons were run on a series of concurrent variable-interval reinforcement schedules, from which baseline matching functions were obtained. An experimental phase followed, in which a second response key was available in one concurrent schedule alternative. For half the birds, the second key was programmed identically with the first; for the other half, the added key was programmed for extinction, with position irrelevant. Comparison of baseline and experimental matching functions revealed no systematic changes in either slope or intercept for birds in the latter group. Systematic shifts in function intercepts in the former group indicate a response bias toward the response-constrained (single-key) schedule alternative. Although contrary to the literature of preference for choice, this finding may be interpretable through an account dealing with imposed variability of responding.

Key words: response class, response bias, matching law, concurrent schedules, key peck, pigeons

Issues involving the concept of freedom are issues involving some aspect of choice. For example, if an organism is faced with a single possible course of action in a given situation, we tend to think of the organism's freedom as constrained in that situation as compared with one in which several alternatives are available (Catania, 1975; Wicklund, 1974). Several recent experiments have been directed toward assessing whether subjects will tend to prefer free as opposed to forced choices; that is, whether subjects will prefer a greater number of alternative courses of action to fewer possible courses of action. Of course, elements of choice are present in any behavioral context because the organism typically "has the choice" to respond or not. Hence, the terms *free* and *forced* choices are used in this context to describe in a relative sense the range of behaviors that may fall into a molar re-

sponse class (Logan, 1956, 1960), that is, the range of behaviors that are formally eligible for reinforcement.

A number of experiments with both animals and human subjects have demonstrated preferences toward choice alternatives where the molar response class was larger, i.e., where a wider range of responses were capable of being reinforced. For example, Voss and Homzie (1970) reported that rats in a maze-running situation preferred paths which included an alternate path as opposed to single-path routes.

The most extensive investigation of preference for alternatives was recently reported by Catania (1975). Here pigeons were exposed to concurrent-chain reinforcement schedules where pecks on initial-link keys occasionally gained access to either one or two terminal-link schedule keys. Relative response rates on the initial-link keys revealed systematic preferences for that alternative where responses on either of two response keys could be reinforced. Catania (1975) ran extensive control experiments to determine the contributions of stimulus number, informativeness, and variety. Of these variables, only the information value of the alternatives affected preference to an appreciable degree, a finding consistent with previous data regarding information and choice (e.g., Bower, McLean, & Meacham, 1966; Hendry, 1969). In these instances, "in-

formative" conditions are those in which alternative conditions of reinforcement are associated with differential discriminative stimuli.

An alternative method of assessing preference in the operant context is provided through the use of simple concurrent reinforcement schedules (Catania, 1966). Concurrent operant behavior has been the subject of increasing empirical and theoretical interest in recent years (e.g., de Villiers, 1977). For example, a sizable literature supports the following matching relation between behavior on two concurrently available reinforcement schedules and the reinforcements obtained on those schedules:

$$\frac{P_1}{P_2} \text{ or } \frac{T_1}{T_2} = k \left(\frac{r_1}{r_2}\right)^a . \tag{1}$$

P_1 and P_2 represent numbers of responses emitted on each of the schedule alternatives, T_1 and T_2 represent the time spent in each of the schedule alternatives, r_1 and r_2 represent the number of reinforcements obtained on the schedule alternatives, and a and k represent empirically determined constants.

At the interpretive level, several authors (e.g., Baum, 1974; Miller, 1976; Rachlin, 1971) have recently argued that the matching law in terms of response or time allocation may be viewed as a measure of the relative value of the alternatives for the organisms, as given by the following equation:

$$\frac{P_1}{P_2} \text{ or } \frac{T_1}{T_2} = \frac{V_1}{V_2} , \tag{2}$$

where V_1 and V_2 represent the values of the concurrent alternatives. Viewed in this way, deviations of experimental results from matching to reinforcement ratios as given by Equation 1 (i.e., where $a = k = 1.0$) may represent, in certain circumstances, reinforcement in the experimental situation from sources not accounted for in terms of the obtained reinforcements alone.

To elaborate, Baum (1974) has described two types of deviation from matching which are based upon Equation 1. Deviations from unity of the exponent a has been termed undermatching when its values fall short of 1.0, which appears to be a frequent outcome in concurrent schedule studies (Myers & Myers, 1977). Undermatching indicates that preferences are less extreme than would be predicted from the reinforcement ratios or that there is a relative indifference between the alternatives over a range of schedule values. Baum (1974) has speculated on the basis of limited data that undermatching may involve a lack of discrimination between the schedule alternatives.

The second type of deviation from matching described by Baum (1974) is that of response bias, which is said to occur when the value of the parameter k deviates systematically from 1.0 when preference is tested over a range of pairs of schedule values. Response bias in this sense indicates a condition where the subject displays preference for an alternative which is systematically greater than would be predicted by the programmed reinforcement contingencies alone (i.e., obtained reinforcements in Equation 1).

The question asked in experiments investigating preference for alternatives is whether there is a greater value in situations where a greater choice of actions is possible as compared with one in which the range of actions is relatively constrained in terms of the possible variants within the formally defined response class. In the context of operant behavior, an alternative method to the concurrent-chain procedure for assessing preference is to give pigeons a series of choices between two independent and concurrently programmed VI reinforcement schedules, one programmed on two response keys, and the other on a single response key. If there is a value in the larger response class per se, this value would be expected to be manifested in the form of a systematic response bias (Baum, 1974) over what would be predicted on the basis of obtained grain reinforcement alone.

In the present experiment, pigeons were exposed to the contingencies described above through the use of the changeover-key method of programming concurrent schedules (Findley, 1958). In this procedure, each independent reinforcement schedule is associated with a distinctive stimulus on a given key or set of keys. Changing from one schedule to another is accomplished by responding on a separate changeover key.

Using the Findley (1958) method, a two-key versus one-key experimental condition was compared to a baseline condition. During baseline, a single programmed schedule key was available in either alternative. In the experi-

mental condition, a second illuminated schedule key was introduced in one of the schedule alternatives. Further, number of key routes to a reinforcer was confounded with number of keylights. Catania (1975) has noted that conditions which control for number of lit keys in two-key versus one-key availability will confound the latter choice with an informative alternative. The control condition for a separate group of subjects therefore involved the addition of a same-colored key to one of the two schedule alternatives that was programmed for extinction (rather than identically programmed for the VI schedule), with position alternating over successive reinforcements.

METHOD

Subjects

Twelve adult male White Carneaux pigeons, experimentally naive at the beginning of training, served. All subjects were reduced to 80% of their free-feeding weights before training and maintained at these weights throughout the experiment.

Apparatus

Three standard Lehigh Valley three-key pigeon chambers were used; their interior dimensions were 34 by 30 by 36 cm. The chambers were enclosed in sound-attenuating boxes with exhaust fans providing additional masking from extraneous sounds. The three response keys each had a diameter of 2.5 cm and were arranged horizontally on a line 26 cm above the chamber floor, with a distance between adjacent key centers of 6.5 cm. A minimum force of approximately .15 N was required for microswitch closure. A one-plane readout projector was mounted behind each response key, enabling the use of various color stimuli (white, green, red). Reinforcement was 3-sec access to mixed grain through a 5.1- by 5.7-cm hopper opening in the center of the panel and located 13 cm above the chamber floor. During grain presentations, a hopper light was illuminated and the key lights darkened. No houselights were used. Programming equipment was located in a separate room and consisted of transistorized digital logic, two VI tape timers, and relay interface. Data were collected on impulse counters.

Procedure

Preliminary training. All birds were initially trained to eat from the hopper during 3-sec grain presentations arranged according to a variable-time (VT) 30-sec schedule. When each bird was reliably eating from the hopper, handshaping of the key-peck response began to the right-hand key, which was illuminated white.

On completion of 50 continuously reinforced responses, each bird was placed on a variable-interval (VI) 30-sec reinforcement schedule. This schedule was programmed for either the left-hand or center key in the three-key display, alternating irregularly across successive reinforcements. The programmed schedule key was illuminated either green or red, alternating several times within each training session. When each bird had collected 200 reinforcements on the VI 30-sec schedule, baseline conditions were instituted.

Baseline phase. In baseline and experimental phases, two VI reinforcement schedules were programmed concurrently according to the Findley (1958) changeover-key procedure. In the extension of this procedure to the three-key display, the subject could gain access in an alternating fashion to either of two independently programmed VI schedules by pecking the right-hand key. This key was illuminated white throughout the experiment and will henceforth be called the changeover key.

In the baseline phase, a given VI schedule alternative was programmed on a single key, illuminated either green or red. For a given VI schedule alternative, the illuminated schedule key appeared on either the left-hand or center key of the three-key display, henceforth to be called the left and right main keys, respectively. The position of the illuminated schedule key alternated irregularly and independently for the two schedules on the two main keys across successive reinforcements, and responding on the darkened main key had no scheduled consequences. A 2-sec changeover delay (COD) was programmed such that, if a reinforcer was set up prior to entering a given VI alternative, the reinforcer could not be collected until at least 2-sec had elapsed on entering that alternative.

The concurrent VI VI schedules were programmed through the use of two independent and free-running VI tape timers that assigned

reinforcers simultaneously to the three experimental chambers. The tape timers continued to run when reinforcement was set up, but response rates were generally such that very few scheduled reinforcers were not collected. All VI schedules were constructed according to the Fleshler and Hoffman (1962) progression, with randomized order of interval lengths. The schedule values used on the green and red key alternatives, respectively, were as follows: VI 75-sec VI 300-sec; VI 120-sec VI 240-sec; VI 75-sec VI 75-sec; VI 120-sec VI 60-sec; VI 240-sec VI 60-sec.

All birds were run for daily sessions of 1 hr, with the key color that began the session alternating over days. Reinforcement was available in both schedule alternatives at the beginning of each session. The above concurrent VI VI schedules were administered to all birds in a random sequence, with the restriction that first, last, and equal-value pairs listed above be presented in random sequence first, followed by the remaining two pairs in random sequence. Prior to formal baseline phase sessions, all birds were given two sessions of training on concurrent VI 30-sec VI 30-sec schedules.

In the baseline phase, a given pair of VI schedule values remained in effect until stability was achieved. Stability was defined as achieved when the following two criteria were met: (a) The median of the group mean relative number of responses (number of responses on one alternative divided by the total number of responses for the session other than changeovers) for five sessions did not differ from median of the five previous sessions by more than .05, and (b) there was no systematic upward or downward trend in the group mean relative number of responses over the last three sessions.

Data collected on each subject per session were the following: (a) response allocation—number of pecks on each of the two schedule alternatives; (b) time allocation—time in seconds spent in the presence of each of the two schedule alternatives (counters accumulating time were disabled during hopper presentation); (c) reinforcements obtained on each of the two schedule alternatives; (d) number of changeovers.

Experimental phase. On achievement of group stability at all five concurrent VI VI schedule conditions, the birds were randomly divided into two groups. Birds in Group E

(two keys versus one key) were given a concurrent schedule choice between a VI schedule programmed on one of the two main keys (red) and a VI schedule programmed on both of the two main keys (green). In the first alternative, the position of the red-illuminated schedule key alternated irregularly on the main keys across successive reinforcements, with the darkened main key inoperative as before. In the second alternative, both main keys were operative and illuminated green. Programming was such that the two green keys provided alternative key routes to the same scheduled reinforcer. That is, the pigeon could distribute pecks in any manner between the two green keys during the scheduled interval, and the first peck on either key on termination of that interval would be reinforced. As in the baseline phase, the bird could gain access to either of the two concurrent VI VI schedules (red or green) by pecking the white-illuminated changeover key.

Birds in Group C (control) were exposed to the same condition as Group E with the difference that in the green-illuminated two-key alternative, only one of the two lit keys was programmed for VI reinforcement and the other main key was programmed for extinction. The position of the scheduled VI key always alternated irregularly on the two green keys across successive reinforcements.

In the experimental phase, all birds were exposed to the five concurrent VI VI schedules used in the baseline phase. Procedures determining order of exposure, daily running procedures, and stability criteria were the same for each of the two groups in the experimental phase as in the baseline phase. Data collected were also the same with the exception that, in all conditions where two illuminated keys were available in a schedule alternative, response allocation was subdivided such that responses on the two illuminated keys were recorded on separate counters.

RESULTS

A summary of the sequence of concurrent VI VI schedule conditions, along with group mean frequency data for response and time allocation, reinforcements obtained, and changeovers is presented in Table 1. It can be seen that stability was achieved quite rapidly over all schedule conditions in the baseline phase (upper half) and experimental phase (lower

Table 1

Summary of conditions and absolute frequencies for the baseline (upper half) and experimental (lower half) phases. The data are means over the six birds in each group and over the last five sessions of each condition. Variable-interval schedule values (sec) responses, time (sec), and obtained reinforcements are shown for both the green (G) and red (R) schedule alternatives. The experimental phase green alternative is further divided into left (L) and right (Rt) keys.

VI scheduled (sec.)		Sessions	Responses		Time (sec.)		Reinforcements obtained		Change-overs	Group
G	R		(L) G (Rt)	R	G	R	G	R		
75	75	12	1520	1459	1748	1773	41.65	40.31	365	C
		12	1928	1794	1764	1698	14.33	39.53	485	E
240	60	10	633	2233	749	2692	12.40	52.73	337	C
		10	927	2357	892	2551	12.97	50.77	424	E
75	300	12	2206	619	2693	732	43.27	9.30	295	C
		12	2395	918	2593	839	43.43	10.37	354	E
120	60	10	1092	2133	1195	2234	24.90	52.93	415	C
		10	1384	2247	1227	2161	24.57	50.33	501	E
120	240	11	1827	1191	2133	1309	27.43	12.97	365	C
		11	2024	1480	2097	1263	26.07	12.60	466	E
75	75	11	762/735	1573	1579	1767	38.67	39.57	595	C
		10	827/846	1969	1602	1640	37.40	38.40	463	E
75	300	10	1045/1164	729	2421	789	39.43	9.53	259	C
		10	1279/949	1058	2408	846	41.37	10.20	383	E
240	60	11	326/470	2152	831	2509	12.27	52.07	335	C
		13	431/350	2478	801	2416	11.93	50.13	338	E
120	240	14	902/907	1011	2088	1104	25.50	12.23	263	C
		13	919/510	1581	1732	1449	24.90	12.63	334	E
120	60	16	426/461	2052	1028	2380	23.77	52.17	318	C
		11	517/324	2232	968	2172	23.90	49.00	348	E

half), with group stability typically achieved within two or three sessions after the minimum number of 10. Application of the stability criteria to individual birds yielded comparable results.

The relational aspects of the data are presented graphically in Figure 1, which shows group mean choice data for response and time allocation measures. The logarithms of the ratios of the numbers of pecks on the two schedule alternatives and the ratios of the time spent in the presence of the two schedule alternatives are shown as a function of the logarithm of the obtained reinforcement ratios. The points represent means over the six birds in the designated group and over the last five sessions of each concurrent schedule condition. Individual relative response and reinforcement rates were calculated on a session-to-session basis and then averaged. The light solid line indicates the locus of matching, the heavy solid lines indicates the fitted baseline function (circles), and the dashed lines indicate fitted experimental functions. The straight lines were fitted by the method of least squares, and the equation for each is shown along with values of bias parameter k (the antilogarithm of the y-intercept) and the values of e, a measure of goodness of fit (proportion of variance unaccounted for by the fitted straight line).

Figure 1 shows that the relationship of the response and time allocation group data to reinforcement ratios is adequately described by a linear function. In no case was less than 90% of the variance accounted for by the fitted lines, and for baseline functions the fits were superior on both measures (not less than 99%) to the experimental functions for either group. It should be noted here that the possible range of variation of points around the matching line depends on the ratio of the number of responses or number of seconds allocated to a schedule to the number of reinforcements obtained on that schedule. In a response-contingent procedure, as the number of (say) pecks approaches the minimum number of one per reinforcement under concurrently programmed schedules, a trivial case of matching
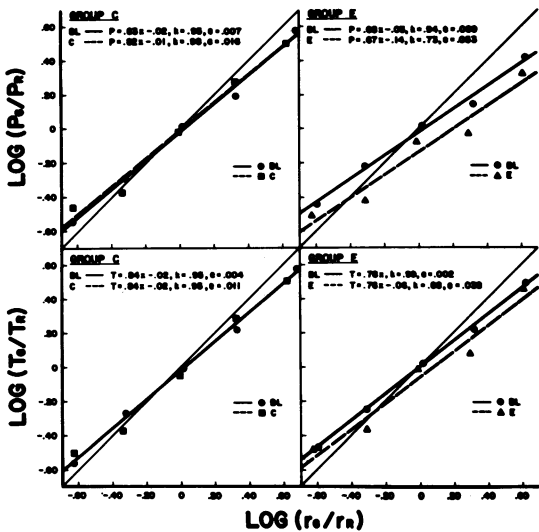
Fig. 1. Group Mean Choice Data: ratios of response (P) and time (T) allocated to the green (G) and red (R) schedule alternatives are shown as a function of obtained reinforcement (r) ratios. Points represent means over six birds and over the last five sessions of each concurrent schedule condition. Equations are shown for best-fitting straight lines along with bias parameter k (antilogarithm of the y-intercept) and values of e (residual error). The light solid lines indicate the locus of matching, the heavy solid lines are fitted to baseline values (circles), and the dashed lines are fitted to experimental values (squares for Group C; triangles for Group E).

is approached as the possible range of variation is constrained. It is characteristic of behavior under interval schedules, however, that these ratios are high (e.g., Ferster & Skinner, 1957; Herrnstein, 1970), and Table 1 confirms this fact in the present experiment.

Figure 1 shows that the slopes (a) of the fitted lines are less than 1.0 in all cases, and that they are nearly equal from baseline to experimental phases for each group and on both response and time allocation measures. Slopes are also somewhat greater for Group C on both measures for the averaged data. The baseline and experimental functions for Group C are superimposed for averaged time allocation data, and this is reflected in the presented values of k. These equal or near-equal values of k indicate that the addition of a second green-illuminated but inoperative key in the experimental phase did not systematically affect preference relative to the baseline single-key schedule alternatives, even though the position of the operative green key

in the experimental phase was unpredictable over successive reinforcements. For group E, however, decreases in values of k from the baseline phase to the experimental phase are seen on both measures, with the decrease on response allocation data (.94 to .73) being considerably larger than that for time allocation data (.99 to .88). This indicates that when a second operative key was added to the green-illuminated schedule alternative in the experimental phase, preference tended to increase to the red-illuminated single-key schedule alternative relative to baseline conditions. Inspection of group mean absolute response rates revealed that this shift in relative rates in Group E was due to a combination of decreasing local response rates to the green keys and increases to the red key. The systematic nature of the shift in preference is supported by the fact that the slopes remained nearly constant while the intercepts decreased, indicating that the shift in bias toward the single-key alternative was not specific to which schedule had the greater reinforcement density. Additional support is gained by examining the individual data points. Although for the time allocation data in the shift in k for Group E is accounted for by only two of the five points (the intermediately disparate concurrent schedule values), the shift for response allocation data occurred at all five of the varying concurrent schedule conditions. These trends may also be seen at the level of individual subject data.

Figure 2 presents response allocation choice data for individual pigeons in Group C. An examination of slope differences between baseline and experimental phases reveals no systematic difference in direction across pigeons, with three birds showing a decrease in slope (Pigeons 253, 255, and 261), two birds showing an increase (Pigeons 259 and 260), and one bird showing no change (Pigeon 254). Similar nonsystematic trends are shown for values of k, with three birds showing an increase (Pigeons 253, 254, and 260) and three birds showing a decrease (Pigeons 255, 259, and 261). The only clear change in response bias in Group C is shown by Pigeon 254, as evidenced by the equal slopes in baseline and experimental functions and the large increase in the value of k (.84 to 1.29) highlighted by the division of the five baseline data points from the five corresponding experimental determinations by the matching line. Taken together,
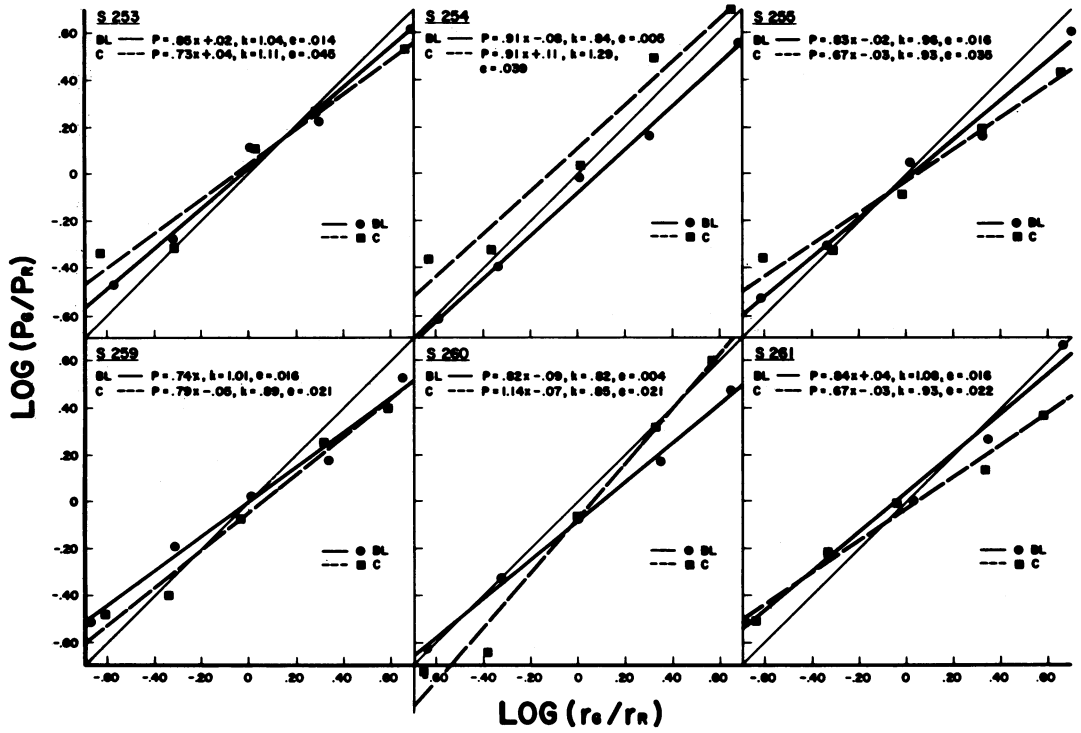
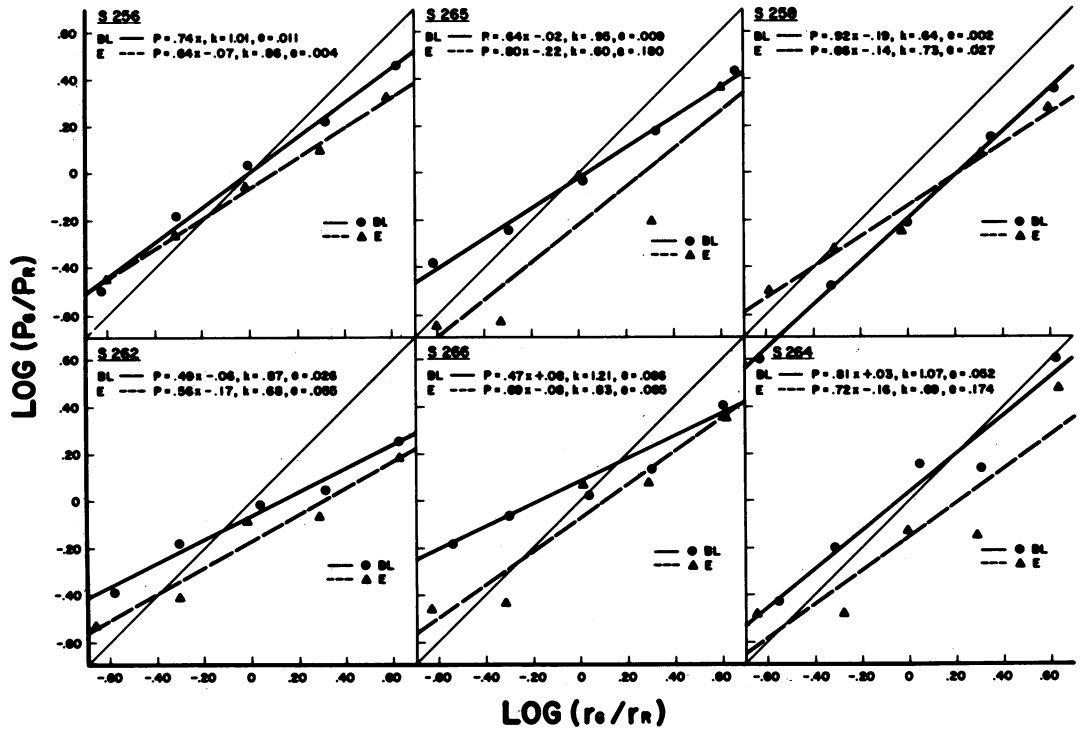Fig. 2. Group C response-allocation data for individual birds (see legend for Figure 1).

Fig. 3. Group E response-allocation data for individual birds (see legend for Figure 1).

these data indicate a rather strong bias in favor of the two-keylight (green) schedule alternative relative to baseline conditions for Pigeon 254.

Figure 3 presents response allocation choice data for individual pigeons in Group E. In this group as well as in Group E, changes in slope were nonsystematic across birds, with half showing a decrease (Pigeons 256, 258, and 264) and half showing an increase (Pigeons 265, 262, and 266). Experimental deviations from baseline in values of k, however, show a clear trend across birds toward lower values. With the exception being Pigeon 258, five birds showed decreases in at least four of the five concurrent schedule conditions tested, and in some cases these decreases were quite large (e.g., Pigeons 265, 266, and 264).

Figures 2 and 3 support the averaged response allocation data of Figure 1 in showing a systematic bias across pigeons toward the single-key (red) schedule alternative when a second operative key became available in the concurrent (green) schedule alternative. No such systematic bias was found across pigeons in Group C, where a second illuminated but inoperative key was presented on the green-signaled schedule in the experimental phase.

An examination of individual subject trends for time allocation data yields similar but less definitive results. Figure 4 presents time allocation choice data for individual pigeons in Group C. Results shown here are quite similar to those found under response allocation measures (cf. Figure 2), although in general the differences between baseline and experimental functions are less extreme (e.g., Pigeons 254, 259, and 261). Nonsystematic trends across birds are again evident for Group C for time allocation data, and also evident are the individual trends observed in Figure 2 (e.g., Pigeon 260 for slope; Pigeon 254 for intercept).

Figure 5 presents time allocation choice data for the individual pigeons in Group E. For these birds as well, the experimental effects are less extreme when compared with response allocation data (e.g., Pigeons 256 and 262; cf. Figure 3). Figure 5 shows that the bias effect seen in five of six birds in response allocation toward the single-key (red) schedule alternative is observed here in three of six cases (Pigeons 265, 266, and 264). It is also evident that
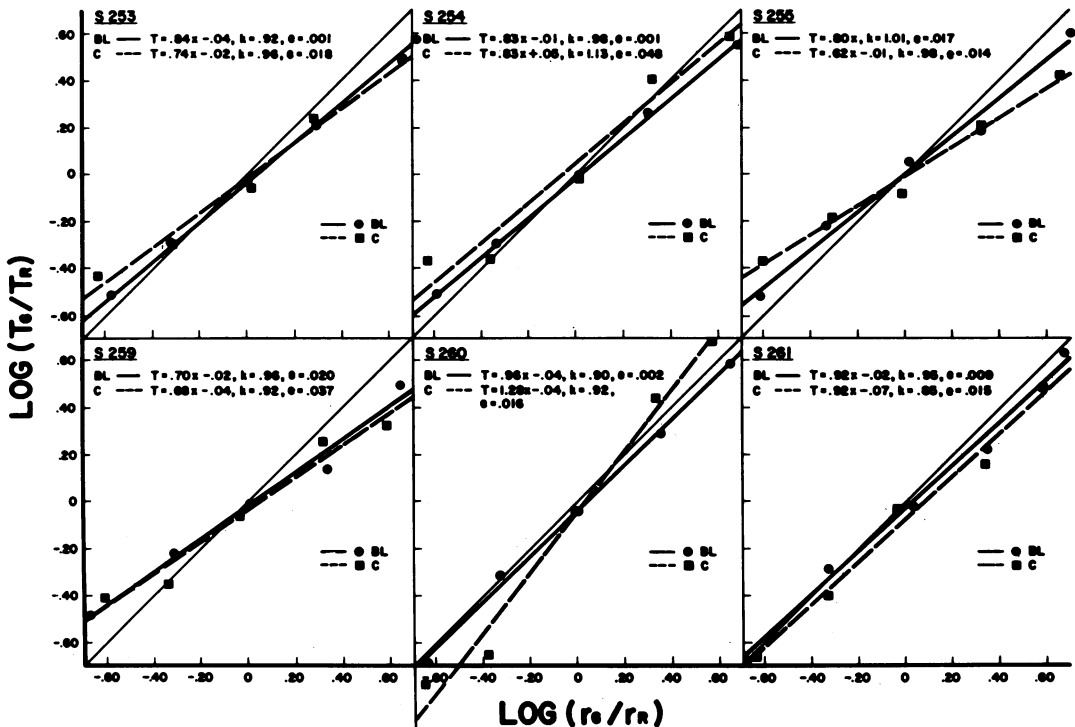

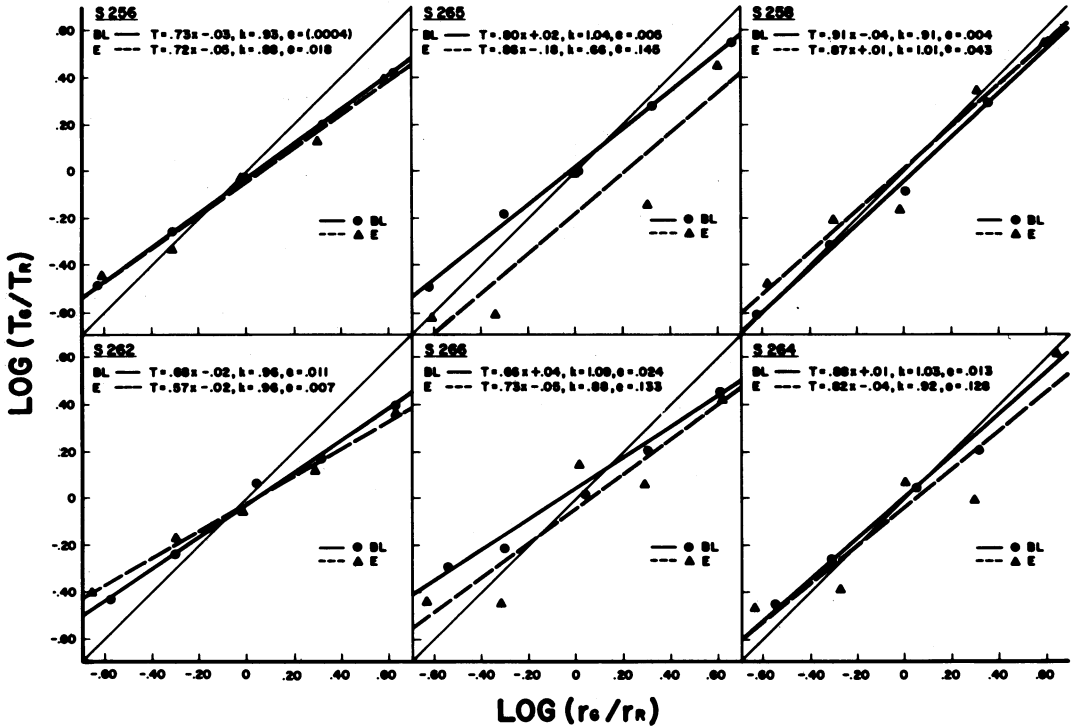Fig. 4. Group C time-allocation data for individual birds (see legend for Figure 1).

Fig. 5. Group E time-allocation data for individual birds (see legend for Figure 1).

the primary source of the bias in these three birds is only two of the five concurrent schedule conditions (*conc* VI 120 VI 240; *conc* VI 120 VI 60). Hence, the time allocation data provide some evidence for the single-key bias effect seen more clearly on the response allocation measures.

Two additional and rather pervasive trends may be noted from Figures 1 through 5. First, for 10 of 12 birds on either measure, straight lines were better descriptions of relationships obtained under baseline than under experimental conditions. Indeed, the larger deviations from linearity (e.g., Pigeons 265 and 264, Figures 3 and 5) give some indication of the possible range of variation of the plotted points from the matching line. Second, of 24 straight lines fitted to data points on either measure, all but one (the experimental function for Pigeon 260, Figures 2 and 4) yielded slopes of less than 1.0.

In the experimental phase, all birds were presented with a second illuminated key in the green-signaled VI schedule alternative, with the single red key concurrently available for responding on the other VI schedule as in the

baseline phase. For Group C, only one of the two green keys were operative, and their position varied unpredictably on the two keys over successive reinforcements. For Group E, both green keys were operative with identical programmed consequences. A survey of the group mean data of Table 1 for the experimental phase (lower half) shows that responses were distributed on the two green keys with a rough equivalence for Group C and with indications of a left position bias in Group E. The group averages over position tend to obscure the response distribution patterns of individual birds, as can be seen in Figure 6. Here the relative preference measure indicates the number of pecks to the green key with the greater number divided by the sum of the pecks on both green keys. Hence, Figure 6 shows the average tendency for the birds in a group to peck one key as opposed to the other regardless of position. Figure 6 also shows a clear tendency for birds in Group E to peck only one of the two green keys, as compared with the birds in Group C, which tended to distribute pecks more equally. That these trends are not apparent from the group data of Ta-
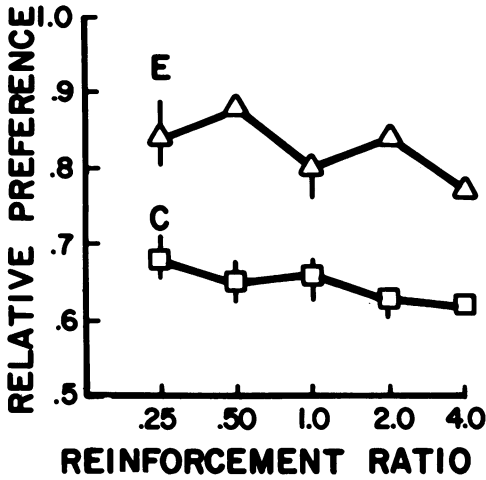
Fig. 6. Relative preference for one key over the other in the green-signaled (two-key) schedule of the experimental phase. Relative preference measure indicates number of pecks to the key with the greater number over the sum for both keys. The points are means over the birds in Group C and Group E over the last three sessions of each condition, with the range indicated. Values are shown as a function of the programmed reinforcement frequency ratios of the five concurrent schedule conditions.

ble 1 is indicative of individual differences among birds in Group E regarding preferred position. This was confirmed by inspection of session data for individual birds, along with a reasonable consistency of preference over sessions and schedule conditions. An inspection of session data also revealed some indication of a chamber effect regarding a particular position preference, possibly reflecting small differences in response criterion (e.g., force requirement) or feedback (e.g., microswitch clicks) on the two main keys. Finally, it should be noted from Figure 6 that the differences between and within groups on distribution of responses to the green keys were apparently unaffected by varying concurrent schedule conditions.

A finding often reported in studies of concurrent operant behavior is that rate of changeover between .a pair of VI schedules is in part an inverse function of the dispartity of the VI schedule values (e.g., Baum, 1975, 1976; Herrnstein, 1961; cf. Stubbs, Pliskoff, & Reid, 1977). Figure 7 presents data supporting this finding in the present experiment. The inverted U-shaped functions show that changeover rate tended to be lowest when the concurrent VI VI schedule values were at maximum diver-
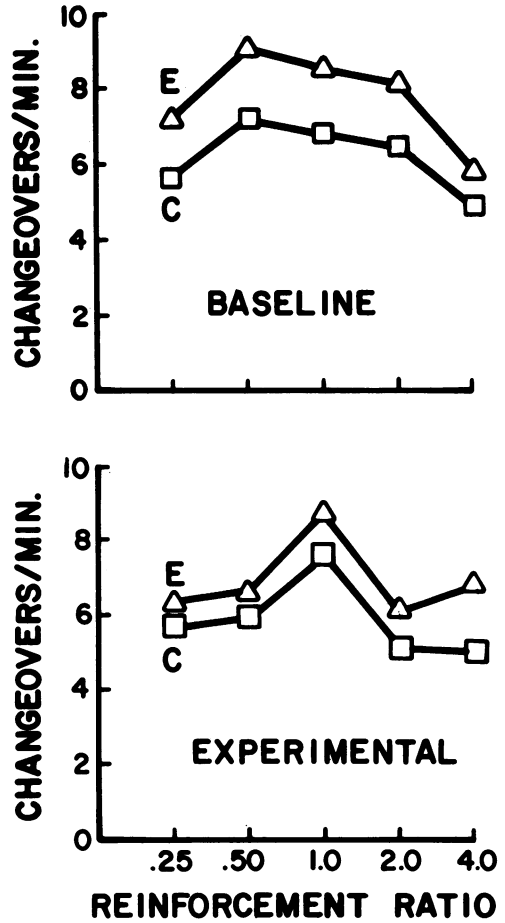

Fig. 7. Changeover rate as a function of programmed reinforcement frequency ratios for baseline and experimental phases. The points are means over birds in Group C and Group E over the last three sessions of each condition.

gence. This trend is found in both baseline and experimental phases, and in both groups. The overall higher changeover rates for Group E in the experimental phase is not attributed to treatments, inasmuch as such a difference was also found in the baseline phase wherein all birds were treated. equally.

DISCUSSION

The generalized matching law as given in Equation 1 provides a basis for the study of various characteristics of concurrent operant behavior. Deviations of the parameter k from unity reflect an invariant asymmetry between alternatives in terms of preference (Baum, 1974). That this asymmetry has been termed

bias implies that its source is not to be found in the relative reinforcements obtained on the alternatives. Hence, the allocation of behavior or time to independent and concurrently available schedule alternatives would presumably reflect the relative value of those alternatives (Equation 2) in terms of some combination of all variables affecting preference over time and conditions (Killeen, 1972; Rachlin, 1971).

Deviations from unity of the exponent a in Equation 1 are poorly understood at present. At least one attempt to vary independently the values of a and k in an experimental context has not met with success (Bacotti, 1977). Although it is now generally established that deviations of a tend to be toward values of less than unity, termed undermatching (Baum, 1974; Myers & Myers, 1977), the variables affecting these trends are not clear.

On interpretation offered by Baum (1974) states that undermatching may indicate a lack of discrimination between the schedule alternatives. Limited data are cited in support of this, though they come from several sources. The clear undermatching trends seen in the present data (Figures 1 through 5) support the generality of the finding (Myers & Myers, 1977) in that preferences were less extreme than would be predicted from obtained reinforcement ratios. However, when the differences in the slopes (a) of the regression lines between the baseline and experimental phases are examined, support for Baum's discrimination hypothesis is not found. That is, in the baseline phase, birds were provided with only color as a basis for discriminating the schedules, and undermatching was the overall result. In the experimental phase for either group, however, the addition of an illuminated key in one of the schedule alternatives provided more stimulus dimensions on which to base a discrimination (number of lit keys, variability of position). The fact that the slopes were not systematically increased across birds (Figures 2 through 5, cf. Figure 1) is damaging to the discrimination hypothesis and points to the need for more work delineating the variables affecting the parameter a.

Inspection of the individual subject data (Figures 2 through 5) and the averaged group data (Figure 1) reveals a systematic bias of preference (reflected in values of k) in Group E toward the single-key (red) alternative, but with no such bias observed in Group C. This latter finding is interesting since a bias was expected toward the single-key alternative in Group C. For this group, the two-key alternative was associated with less certainty, since the position of the operative key varied across successive reinforcements on the two same-colored keys. Other data indicate preferences for the more certain alternative (Bower et al., 1966; Catania, 1975; Green & Rachlin, 1977; Logan 1965). For example, Catania (1975) ran a similar condition in a concurrent-chain procedure with the difference that the inoperative key was correlated with a distinctive key color for one terminal-link schedule. In contrast to the present results, Catania found strong preferences for the informative terminal-line alternative. It is possible that dark inoperative response keys do not function as response "alternatives" in the same way as illuminated keys programmed for extinction. This interpretation is consistent with other aspects of Catania's (1975) data, and may be related to the extended training that pigeons typically receive in pecking illuminated response keys. Such discrimination training was extensive during the baseline phase of the present study.

The single-key bias observed in subjects of Group E is more interesting because such a finding is contrary to the literature of preference for alternatives (e.g., Catania, 1975). The systematic decreases in values of k indicate that when a second, identically programmed key was added to a VI schedule alternative, preference increased to the concurrent single-key schedule alternative. This result implies a bias against the alternative where more key-peck response variations were capable of being reinforced. That the subjects in the two groups came into contact with the differential contingencies is also apparent from the two-key response distribution effects seen in Figure 6. Pecks were more equally distributed for Group C presumably because of the greater probability of reinforcement immediately following a changeover from one green key to the other (Catania, 1966). That is, a pigeon in Group C pecking the currently programmed extinction key will be reinforced for changing over to the alternative green key given that reinforcement has been set up, which is not the case for Group E where changeovers from one green key to the other will be immediately reinforced only when reinforcement is set up while the bird is moving between keys. Figure 6

shows that Group E tended to peck only one of the two keys, with session-to-session data showing the chosen position to vary across birds but remain consistent for individual birds (cf. Table 1).

Figure 3 for response allocation data and Figure 5 for time allocation data show a larger single-key bias on the former measure (cf. Figure 1). The greater relative increase in number of pecks in the single-key schedule as compared to time spent in that schedule indicates a greater relative increase in response rate. Local response rates have been shown to be affected differentially under concurrent schedules by asymmetrical response requirements, as in concurrent ratio interval schedules (Catania, 1966; cf. Bacotti, 1977; Beautrais & Davison, 1977). However, on the basis of these studies a systematic single-key bias would be expected in Group C rather than Group E, since in the former group a greater distribution of pecks and presumably a greater number of changeovers occurred on the two green-illuminated keys as required for minimizing time to reinforcement (Figure 6).

In the experimental phase for Group E, the green-illuminated two-key schedule alternative provided for the reinforcement of a wider range of response relative to the red-illuminated single-key schedule. The results of previous studies (e.g., Catania, 1975; Voss & Homzie, 1970) would provide a basis for predicting a response bias for the two-key schedule alternative; however, the mechanisms underlying such a prediction are usually left unclear in the literature. One approach which may be helpful in conceptualizing preference for larger, formally defined response classes is provided by the response subclass variability hypothesis, originally proposed in a rather different context by Schoenfeld (1950) and extended by Ferraro (Note 1). A general version of this hypothesis states that the strength of a generic or molar response, as measured by persistence in extinction or punishment, is directly related to the variability of quantitative response properties, or subclasses, that were reinforced in training (cf. Logan, 1956, 1960). Hence, those experimental operations which increase the variability of response subclasses reinforced, such as intermittent as opposed to continuous reinforcement (Ferraro & Branch, 1968; Ferraro & Hayes, 1967), will increase the strength of the molar response. Extended

to the present context, one might expect that a response bias would occur to a choice alternative that provides for the reinforcement of a larger number of response classes, reflecting a greater relative response strength (Herrnstein, 1970). It is possible, however, that such a provision could lead to a relative constraining rather than expanding of the response subclasses actually reinforced. That is, the increased availability of alternatives does not necessarily imply the full range of response subclasses will be emitted but, rather, may lead to an "optimal" stereotypy of the molar response.

These issues concerning subclass variability provide a perspective with which to view the bias effects of the present study. In the baseline phase, all birds were reinforced for pecking each of the two keys in each schedule alternative since the position of the operative keys (red and green) varied randomly and independently on the two main keys across successive reinforcements. In the experimental phase for Group C, this imposed variability continued, with the addition that both keys were illuminated in the green schedule alternative and pecks were distributed on the two green keys within successive interreinforcement intervals. For Group E, however, pecks tended to be limited to only one of the two operative green schedule keys, and variability remained controlled in the red schedule alternative by interreinforcement position shifts of the single operative key. Hence, although the birds in Group E were given the "freedom to choose" between the two identically programmed green keys, they tended to respond to only one position; thus, the imposed variability of position in the concurrently available (red) schedule across reinforcements may have provided the basis for greater relative molar response strength to that schedule, as manifested in a relatively greater allocation of pecks or time. There are several issues which complicate this interpretation, however, such as the appropriate measures of response "strength" across different experimental procedures (Deese & Hulse, 1967; Herrnstein, 1970; Logan, 1960; Nevin, 1974).

A more complete understanding of the present results must await further delineation of the mechanisms underlying concurrent schedule matching phenomena. The present findings point to constraints on preference for

larger response classes and may indicate that "preference" in such situations is not governed so much by the expanded opportunities for response variability as it is by the contingencies that control such variability.

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