An Appraisal of Preference for Concurrent versus Mixed-Concurrent Schedules of Reinforcement

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A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

William H. Stevens

August, 1977

AN APPRAISAL OF PREFERENCE FOR CONCURRENT VERSUS MIXED-CONCURRENT SCHEDULES OF REINFORCEMENT

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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DEDICATION

To Liz, whose patience, understanding, and support through the years made everything possible.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the following people whose contributions have directly affected this research: Dr. Donald M. Wilkie, who taught me how to work in a laboratory; Dr. Joseph J. Pear and Dr. Garry L. Martin, who introduced me to operant conditioning and taught excellent courses throughout my years at university; Dr. M. Nahir and Dr. Steven R. Hursh, who served on my advisory committee; Brian Rector, who was always ready to discuss experimental design and equipment problems, and to help with the subjects; Les Bell and Joe Legris, who supplied equipment and advice on its use; Pat Macdonald, who introduced me to the computer; and Malcolm Shooter, who spent hours of his time applying sheer hard work and wizardry to have the computer perform miracles.

Abstract

Pigeons' responses on a key when red or green occasionally produced entry into terminal link associated with that colour. During the terminal links, pecks produced food according to standard schedules or 'mixed-concurrent' schedules. The standard concurrent schedules provided stimuli correlated with the component schedules, whereas the mixed-concurrent schedules provided equal exposure to the stimuli but uncorrelated with the component schedules. There was a tendency towards a preference for standard concurrent schedules, although apparent colour preferences in the initial links tended to obscure this effect. The lack of a strong preference was contrary to results of comparisons of multiple versus mixed schedules with unequal exposures to the terminal link stimuli and intervals but consistent with the small preferences found with equal exposures to the terminal links. Performance measures tended towards matching in the concurrent terminal link and towards equal distribution between conditions in the mixed-concurrent terminal link.

REVIEW OF THE LITERATURE

The present study was based primarily on results which have been accumulated by researchers working in two areas: that of multiple and mixed schedules and that of concurrent schedules. The relevant research is reviewed below.

Multiple and Mixed Schedules A multiple schedule of reinforcement arranges reinforcers in accordance with two or more schedules which alternate and each of which are associated with a separate stimulus. For instance, a multiple fixed-interval ten second fixed-ratio fifty schedule (MULT FI 10 FR 50) would operate as follows:

During the FI component, a stimulus, such as a red light, would be present. The first response after ten seconds had elapsed would produce a reinforcer. After a further ten seconds had elapsed, the first response to occur would again produce a reinforcer. This situation, with the red light illuminated, would continue for the duration of the FI component. When the FR component began, a different stimulus, such as a green light, would appear and remain for as long as the FR component lasted. During the FR component, every fiftieth response would produce a reinforcer. The duration of each component would be determined by the experimenter.

A mixed schedule of reinforcement differs from a multiple schedule in only one respect: there are no separate stimuli

associated with each component. A mixed fixed-interval ten second fixed-ratio fifty schedule (MIX FI 10 FR 50) would operate exactly as the above multiple schedule except that there would not be a red light and a green light correlated with the components. Instead, a red light might remain on throughout the entire experimental session, or red and green lights might alternate independently of the presence of each schedule.

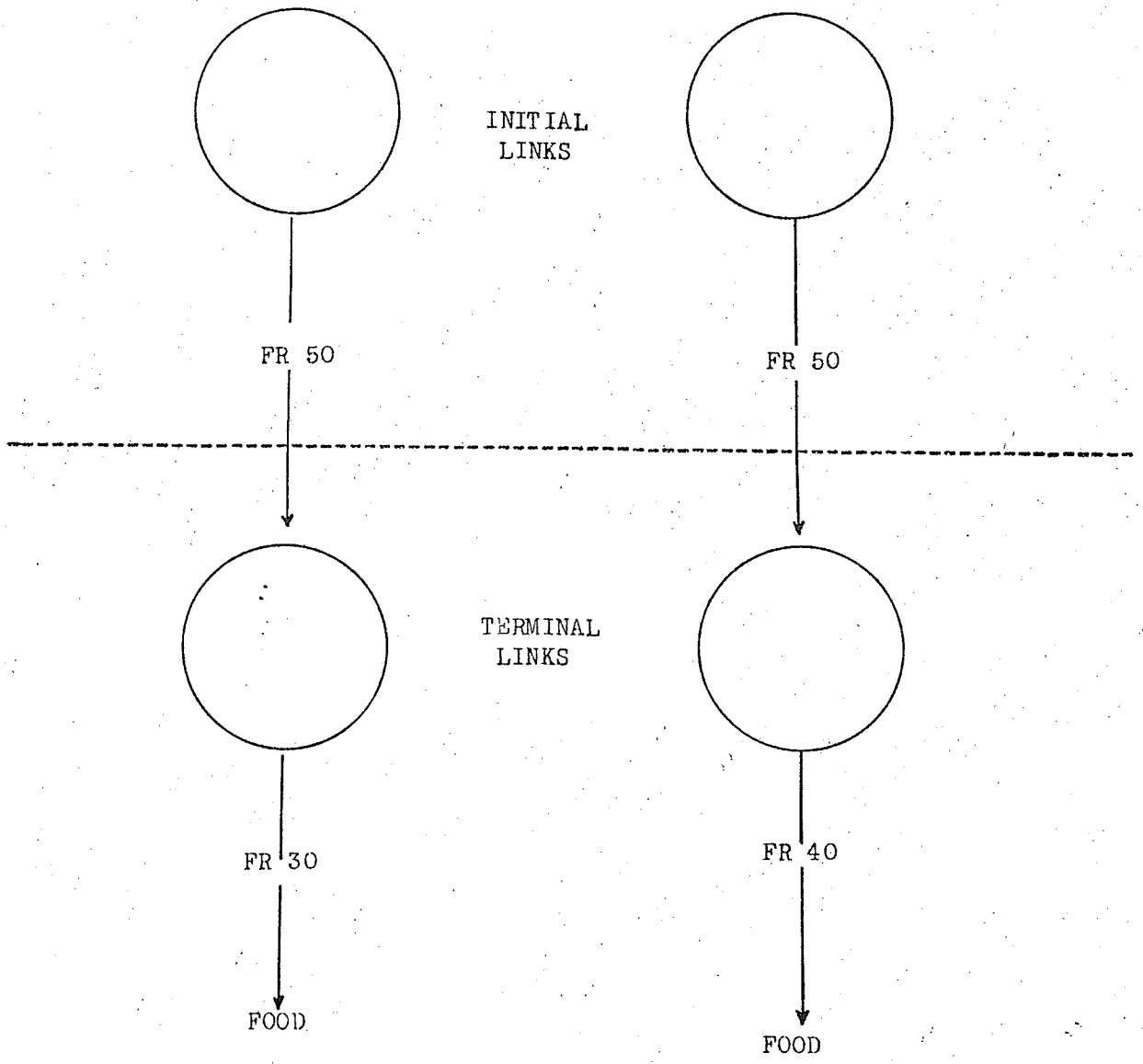
A number of studies have shown that subjects appear to prefer multiple schedules to mixed schedules. Prokasy (1956) used a goal-box technique to compare conditions analogous to mixed and multiple schedules. When one goal box signalled the delay to reinforcement (analogous to a multiple schedule) and the other goal box had no stimulus correlated with the delay to reinforcement (analogous to a mixed schedule), it was found that rats preferred to run to the signalled goal box.

Bower, McLean, and Meacham (1966), using a discrete trial procedure, exposed pigeons to two response keys, one displaying a vertical line and the other a horizontal line. A single peck on the key with the vertical line turned the key red or green and darkened the other key. Responses on the key when red were reinforced with grain on an FI 40 second schedule and when green on an FI 10 second schedule. A single peck on the key with the horizontal line turned the key yellow and darkened the other key. Responses were reinforced on the same schedules as in the presence of red and green except that the key would be yellow when either schedule was in effect. The birds all pecked the key with the vertical line a great deal more than the key with the

horizontal line; that is, the key which produced the multiple-type schedule was preferred to the key with the mixed schedule.

Hendry (1969), in one of a series of experiments with pigeons (experiment B4), compared MIX FR 10 FR 90 schedules with MULT FR 10 FR 90 schedules by means of a two-key concurrent-chain procedure. In such a procedure, outlined in Figure 1, the subject has two concurrently available manipulanda upon which to respond. Responses on one key occasionally produce a stimulus associated with a "terminal link" of the chain. For instance, a pigeon might respond on the left of two keys in a conditioning chamber. Every fiftieth response might cause the key to turn red. The initial link of the chain would in this case be a fixed-ratio fifty (FR 50) schedule. When the key turns red, the pigeon's thirtieth response might produce primary reinforcement. If this situation was consistent for pecks on the left key, the terminal link would be said to be a fixed-ratio thirty (FR 30) schedule. A different terminal link could be used on the right key, but both keys would be available during the initial links. As soon as the terminal link was entered on either key, the opposite key would become dark and inoperative. The sequence on each key would be a chain; responses would first produce the stimulus associated with the terminal link, then further responses would produce primary reinforcement according to a schedule selected by the experimenter. In Hendry's experiment, the initial links were FR 10 schedules and the terminal links were MIX FR 10 FR 90 and MULT FR10 FR 90 as mentioned above.

Figure 1. The concurrent chains procedure. In the initial links responses on either key will produce a terminal link according to concurrent FR 50 schedules. In one terminal link, food is produced is produced according to a FR 40 schedule. Entry into either terminal link causes the other key to become dark and inoperative.


INITIAL
LINKS
FR 50
FR 50
TERMINAL
LINKS
FR 30
FR 40
FOOD
FOOD

Hendry found a marked preference (measured by per cent of entry into the terminal links) for the multiple schedule. This ranged from 75 per cent to 100 per cent over many sessions. It was also found that responses reinforced by the appearance of the multiple schedules were emitted at a higher rate than those reinforced by the appearance of the mixed schedules.

Wilton and Clements (1971a) found that response rates of pigeons were higher when responses produced stimuli correlated with outcomes of food and no food than when responses produced stimuli uncorrelated with outcomes. This was found to be true when (a) the responses produced only the stimuli but outcomes (food or the beginning of a new trial) were programmed to occur even in the absence of responding, and (b) the outcomes and stimuli were contingent upon a response. In the latter case, the response would first produce the stimulus, which would be present for thirty-five seconds before the outcome occurred. The outcome-correlated stimuli, then, maintained higher response rates than those not correlated with the outcomes. This could be considered analogous to a situation involving multiple and mixed schedules.

Kendall (1972) found that the opportunity to obtain reinforcers according to multiple schedules maintained a higher rate of responding by pigeons than did the opportunity to obtain reinforcers according to mixed schedules. Kendall trained his pigeons to peck a dark key which would produce either a red or green light on a FR 5 schedule. During the sessions in which the multiple schedules were in effect, red was correlated with a 120-second delay to reinforcement and green with a 15-second

delay. During the sessions in which the mixed schedules were in effect, the delays were not reliably signalled by the lights. The above two conditions were compared to a baseline condition in which delays in both red and green were fifteen seconds. The response rates of all birds increased in the multiple-delay condition above the rates in the equal-delay condition, while there was no such increase when the conditions were changed from the equal delays to mixed delays.

Wyckoff (1952) showed that the stimuli in a multiple schedule can function as positive reinforcers. In a study with pigeons, either of two consequences occurred at the end of thirty-second intervals: (a) the first peck was reinforced with grain; or (b) another interval began. This is analogous to a MIX FI 30 sec. EXT schedule. For one group of birds, stepping on a pedal on the floor produced either of two lights correlated with the current schedule of reinforcement. This phase was termed "differential reinforcement". Stepping on the pedal would produce a situation analogous to a MULT FI 30 sec. EXT schedule. The proportion of time spent on the pedal was significantly higher in this phase than in a "nondifferential reinforcement" phase in which the key colour was not correlated with the schedules of reinforcement.

Hursh and Fantino (1974) have pointed out that the above studies serve only to provide qualitative demonstrations of the reinforcing properties of the schedule-correlated stimuli of a multiple schedule. They do not provide adequate quantitative data, which, as Hursh and Fantino suggest, would permit a

comparison of the magnitude of multiple-schedule preferences with preferences induced by other reinforcement parameters, such as delay or amount of reinforcement. In studies such as those reported by Bower et al (1966) and Hendry (1969), the large preferences may have resulted from the particular procedures employed. Hursh and Fantino point out that "even a slight difference between the schedules would be expected to produce a large preference because there was no contingency to maintain responding for the non-preferred alternatives" (p. 32). With more choice trials terminating with multiple-schedule reinforcements, it is likely that the preference for the multiple schedule will increase, thus causing a progressively larger proportion of such trials to terminate in the same fashion. Such procedures would thus tend to inflate the quantitative estimate of the preference for multiple schedules.

In order to avoid the above difficulty, Hursh and Fantino (1974) utilized an often-used preference-testing procedure that is relatively unconfounded by differential rates of reinforcement. This procedure involves the use of variable interval schedules in the initial links. Pigeons respond on two concurrently available keys. Responses on either key occasionally produce the terminal link of the chain along with its correlated stimulus (i.e. a light on that key). When VI 60 second schedules are used in the initial links, the first response following a period of time programmed by the experimenter and averaging sixty seconds produces the terminal link of the chain. When either terminal link is entered, the other key becomes dark

and inoperative. Responding in the terminal link produces primary reinforcement according to a schedule programmed by the experimenter. Hursh and Fantino programmed mixed- and multiple-interval schedules in the terminal links and found that pigeons reliably preferred the multiple schedules to the mixed schedules through a series of replications. The preferences, however, were not as extreme as suggested by past studies which did not control for unequal entries into the terminal links. Hursh and Fantino found large preferences with VI 15 sec. initial links and minor preferences with VI 60 sec initial links. They recommended future tests with some intermediately valued VI schedule, although it is not yet clear what value would provide a sensitive measure of preference and still avoid the complication of unequal terminal link entries.

Concurrent chains with VI initial links equal to sixty seconds or more have been used by a number of investigators to provide sensitive measurement of a number of variables. Autor (1969) has shown that relative response rates in the initial links were correlated with the relative rates of reinforcement in the terminal links. This investigation was carried out before 1960 but it was not published until 1969. Herrnstein (1964a) extended the work of Autor and found that the relative rates of responding in VI 60 sec. initial links were equal to the relative rates of primary reinforcement in the terminal links of the schedule. Herrnstein (1964b) has found a consistent preference for VI schedules when VI and FI schedules were programmed in the terminal links of the concurrent chains. Fantino (1967)

demonstrated that rates in the initial links of concurrent-chains schedules were higher when the responses led to mixed-ratio schedules in the terminal links than when they led to fixed-ratio schedules. A mixed-ratio schedule is one in which alternating fixed-ratio schedules determine the occurrence of reinforcement. Fantino (1968) discovered that terminal links containing simple FI schedules were preferred to terminal links in which reinforcement was contingent upon the emission of responses at a rate either higher or lower than a specified value (differential reinforcement of rates).

The research reviewed above suggests two main points:

1) The concurrent-chains procedure with initial links equal to or greater than sixty seconds is a sensitive one for providing quantitative data on preferences and it has been used for this purpose in a variety of investigations.

2) Multiple schedules appear to be preferred to mixed schedules. Although a number of experiments which have shown this may be questioned on the grounds that the preference was perhaps a function of the procedure used, the investigation of Hursh and Fantino (1974) which controlled for such a possibility also indicated such a preference, although small and not always consistent.

The above findings influenced the design of the present study to a considerable degree, but the results accumulated in another area of research were of no less importance. Research based on the topic of concurrent schedules of reinforcement has also been a primary influence on the present investigation. This

research is briefly reviewed in the following section.

Concurrent Schedules The nature of the relations between concurrent operants and their schedules of reinforcement has been the subject of a number of investigations. Most, if not all, of the investigations have used variations of two standard procedures.

In the two-key procedure, the organism has access to two operanda, each having a separate schedule of reinforcement assigned to it. The organism switches from one schedule to another by moving from one operandum to another (e.g. Herrnstein, 1961).

In the changeover (CO) key procedure, all of the schedules of reinforcement are assigned to one operandum. Each schedule is correlated with a different stimulus, which the organism changes by responding on the CO key (Findley, 1958). The CO-key procedure has the advantage of making the behaviour of switching from one schedule to the other explicit. As a result, it is possible to record the time spent in the presence of each schedule, even if the subject switches from one to the other and back to the first without responding in the presence of the second schedule. A record of the time spent in the presence of each schedule enables the investigator to calculate the relative amounts of time and responses occurring in the presence of each schedule.

The dependent variables which have attracted a great deal of attention in research which has dealt with the manner in which organisms distribute their responses between or among the concur-

rent schedules of reinforcement are:

(1) Relative overall response rate, which is the response rate in the presence of one stimulus or schedule relative to the overall rate and is calculated as follows:

$$\frac{P_1}{P_1 + P_2}$$

where P and P are numbers of responses emitted in the presence of stimulus 1 and stimulus 2 respectively;

(2) Relative time, which is the time spent in the presence of one stimulus or schedule relative to total session time and is calculated as follows:

$$\frac{T_1}{T_1 + T_2}$$

where T and T are the amounts of time spent responding in the presence of stimulus 1 and stimulus 2 respectively;

(3) Relative local response rate, which is calculated as follows:

$$\frac{P_1 / T_1}{P_1 / T_1 + P_2 / T_2}$$

The above measure is a comparison of one local response rate (in this case, response 1 is divided by the time spent in the presence of stimulus 1) to the total of both local response rates (that is, the total of the rate of response 1 and the rate of response 2). This measure differs from the relative overall response rate described earlier (see expression 1) in that the relative local response rate takes into account the time spent in the presence of each schedule.

Expressions (2) and (3) are generally applied only to instances where the CO-key procedure is used, as this provides a measure of the time spent responding in the presence of each schedule. When the two-key procedure is used, a measure is sometimes taken of the time between the initial response on one key and the initial response on the other key in order to calculate the relative time (e.g. La Bounty and Reynolds, 1973).

Under conditions in which a changeover delay (COD), which specifies a minimum time during which reinforcement is unavailable after a changeover from responding on one schedule to responding on the other, is programmed, it has been found that a "matching relationship" exists between relative response rate, and relative reinforcement rate (e.g. Herrnstein, 1961). This relationship has also been found between relative time and relative reinforcement rate (Catania, 1963a). That is, the relative rate of responding and the relative time approximate the relative rate of reinforcement for the schedule of reinforcement being considered. The relative rate of reinforcement is calcu-

lated as follows:

$$(4) \qquad \frac{r_1}{r_1 + r_2}$$

where r_1 and r_2 are the number of reinforcements produced by operants 1 and 2 respectively.

As Davison and Hunter (1976) have pointed out, research on concurrent schedules prior to this decade was carried out to support the suggestions (Catania, 1963a; Herrnstein, 1961) that (1) the ratio of the number of responses on two keys equalled the ratio of the number of reinforcements obtained on the two keys (see equation 5); and that (2) the ratio of time spent responding on the two keys equalled the ratio of obtained reinforcement (Catania, 1966; see equation 6). This response-reinforcement matching relation is expressed algebraically as follows:

$$(5) \qquad \frac{P_1}{P_2} = \frac{r_1}{r_2}$$

or

$$(6) \qquad \frac{P_1}{P_1 + P_2} = \frac{r_1}{r_1 + r_2}$$

Equations (5) and (6) are algebraically equivalent (provided, of course, that $P_2 \neq 0$).

The time-reinforcement matching relation is expressed as follows:

$$(7) \qquad \frac{T_1}{T_2} = \frac{r_1}{r_2}$$

or

$$(8) \qquad \frac{T_1}{T_1 + T_2} = \frac{r_1}{r_1 + r_2}$$

Equations (7) and (8) are algebraically equivalent (provided that $T_2 \neq 0$).

A number of recent articles have suggested that the above equations do not represent the relationships between responses and reinforcements and between time and reinforcements as accurately as more complex equations might, although the time data are normally closer to strict matching than response data (Baum, 1975; Hollard and Davison, 1971; Lobb and Davison, 1975).

Baum (1974a) has found the following equation to fit the response data more closely:

$$(9) \qquad \log \left(P_1 / P_2 \right) = a \log \left(r_1 / r_2 \right) + \log k$$

where a, the slope, and log k, the intercept, are arrived at empirically. For the simplest form of matching, a and k must equal 1 (that is, for equation 5 to hold). This is uncommon, as de Villiers (1977) has shown in comparing the fit of least squares regression lines and best fit lines of 1.0 slope relating log response ratio to log reinforcement ratio for both individual subjects and groups. Equation 9 may also be expressed as follows:

$$(10) \qquad \frac{P_1}{P_2} = k \left(\frac{r_1}{r_2}\right)^a$$

Baum (1974a) has discussed bias and undermatching in relation to equation 10. Baum uses "undermatching" to refer to "a systematic deviation from the matching relation, for preference toward both alternatives, in the direction of indifference" (p. 232). The slope (a) of the lime fitted to equation 10 is less than one in the case of undermatching and greater than one in the case of overmatching.

de Villiers (1977) has argued that undermatching occurs in situations where the experimenter has not properly controlled for all the relevant independent variables, but that the matching relation holds when certain conditions are taken into account, including the subjects' previous experience, the order of presentation of different relative reinforcement frequencies, and the COD duration. Baum (1974a) mentions poor discrimination between alternatives, the COD duration, and the amount of deprivation as being involved in producing undermatching.

The constant k in equation 10 is referred to as "bias" by Baum (1974a) since it indicates the magnitude of preference when apparent equality of reinforcement (r_1 r_2 in equation 10 would predict indifference. No bias exists when k equals one (and log k equals zero). Bias is presumably produced by some uncontrolled variable affecting preference (and therefore stems from the experimenter's

inability to control all the variables in any given experiment). Baum lists four documented sources of bias: (1) response bias; (2) discrepancy between scheduled and obtained reinforcment; (3) qualitatively different reinforcers; and (4) qualitatively different schedules.

Bias is not readily revealed when preference and relative reinforcement are graphed as proportions (equations 6 and 8). Baum (1974a) points out that plotting ratios of time and responses as functions of ratios of reinforcements (equations 5 and 7) in logarithmic coordinates causes choice data to appear just as orderly or more orderly than plotting the proportions. One advantage of using proportions of reinforcement, however, is that it allows the investigator to plot the proportion of reinforcements in situations in which all or none of the reinforcements occur in the presence of one schedule. For instance, in a session in which 60 reinforcements were received in condition 1 and none were received in condition 2, the reinforcement proportion would be 1 if expression 4 were applied:

$$= \frac{r_1}{r_1 + r_2}$$

$$= \frac{60}{60 + 0}$$

$$= \frac{60}{60}$$

$$= 1$$

Using ratios of reinforcement, as in equations 5 and 7, a different situation arises, since r_1/r_2 equals 0/60 or 0. If the labels r_1 and r_2 were applied to the conditions in the opposite fashion, r_1/r_2 would be equal to 60/0, which is undefined. Neither of these values can be expressed as a logarithm.

STATEMENT OF THE PROBLEM

Stevens (1972) found with rats that the relations between the relative response rates and the relative times approximated matching to the relative reinforcement rates when separate stimuli were corelated wtih each schedule of reinforcement, which is typical with concurrent VI schedules. When no separate stimuli were correlated with the schedules, however, matching was not found. The latter schedule was termed a "mixed-concurrent schedule of reinforcement". The above schedules (concurrent and mixed-concurrent) are analogous to multiple and mixed schedules respectively in that (a) there are no separate stimuli correlated with mixed and mixed-concurrent schedules, and (b) there are separate stimuli correlated with multiple and concurrent schedules. Further research on these two similar types of schedules is likely to yield information regarding the conditions which determine whether or not matching occurs.

Hursh and Fantino (1974) and others have examined preferences for mixed versus multiple schedules. The present study is an attempt to extend this work by comparing standard concurrent and mixed-concurrent schedules in order to see if a similar preference exists for situations in which separate stimuli are correlated with the concurrent schedules of reinforcement and not correlated with the mixed-concurrent schedules. This investigation also serves to extend our knowledge of the properties of the

mixed-concurrent schedule, about which very little information has been accumulated, since thus far it has been examined only by Stevens (1972) and Bourland and Miller (1975a, b). This study also serves to provide further information on the use of concurrent schedules of reinforcement in the terminal links of concurrent-chains schedules, which has been reported by Baum (1974b).

METHOD

General Methodology. A single-organism approach (see Sidman, 1960) was used. The present research was aimed at finding effects that can be replicated within and between individual subjects.

Subjects and Apparatus. Four male, adult, experimentally naive White Carneaux pigeons served as subjects. Before the investigation began, access to a normal diet of Purina Pigeon Checkers was restricted until the birds reached approximately 80% of their free-feeding weights. The birds were maintained at this weight by food obtained during experimental sessions and post-session feeding. Water was freely available in the home cages.

The experimental space used was a Lehigh Valley pigeon chamber (interior dimensions 31 cm. X 35 cm. X 35 cm.) with 3 response keys (2.5 cm. in diameter) and a feeder containing Purina Pigeon Checkers on one wall. The feeder was not illuminated during its operation except during the initial training sessions. Operation of the three keys used during the investigation required the following forces: a) initial link R (left-hand) key: 15 g.; b) terminal link R (right-hand) key: 10 g.; c) CO (centre) key: 40 g. Because of the manner in which the procedure was designed, the different force requirements on the keys could not affect the preference for either terminal link or for either concurrent schedule in either of the terminal links.

Stimuli were projected on the rear of two of the response keys by in-line projectors (Industrial Electronics Engineers). Experimental contingencies and events were arranged with standard relay equipment. Recording and scheduling equipment was located in a room separate from that containing the experimental chamber. A fan provided ventilation and a partial masking noise. White noise was continuously present in the room containing the experimental chamber and a house light was on continually during each session.

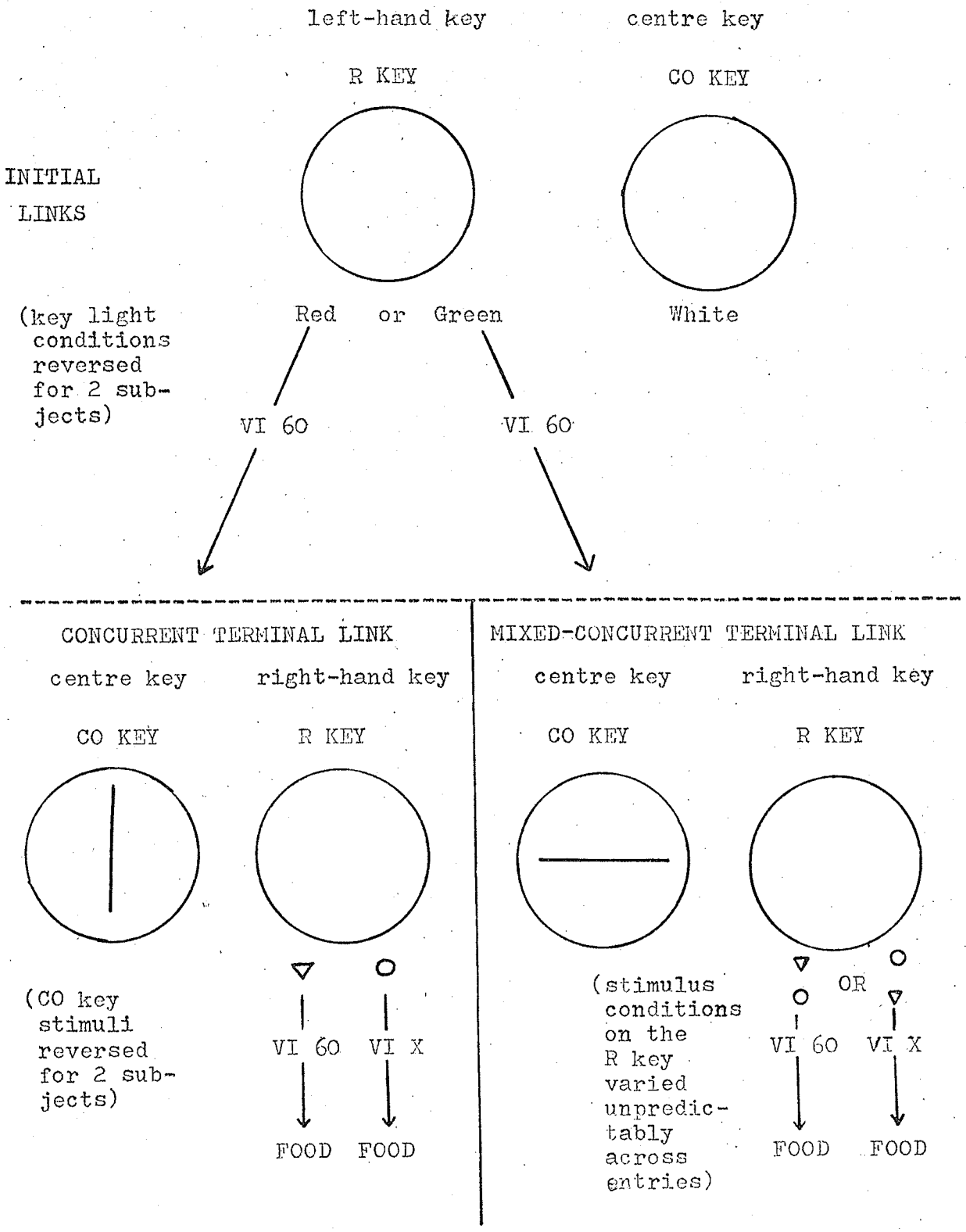
Procedure. All four birds were shaped to peck the centre key and then gradually trained to peck on a VI 90 schedule of reinforcement on all three keys. Only one key was illuminated during each training session. When all birds had experience pecking on all three keys, they were trained to peck the right-hand key on a FR 4 schedule when it was illuminated with a circle, then a triangle, in alternating sessions. All four birds were then exposed to a multiple continuous-reinforcement continuous-reinforcement (MULT CRF CRF) schedule for one session with the left-hand key alternately illuminated with red and green. This schedule was chosen to minimize the development of a preference for red or green. Following the training procedure, the birds were exposed to the first experimental schedule, which is outlined below. During the initial sessions, Birds P-1, P-2, and P-3 pecked at extremely low rates. The three birds were therefore exposed to further training, which consisted of one session of each of the following: (a) A multiple continuous-reinforcement continuous-reinforcement (MULT CRF CRF) schedule

programmed on the left-hand key. The key colour alternated between red and green following each feeder presentation. (b) A MULT CRF CRF schedule programmed on the centre key, upon which vertical and horizontal lines alternated following each feeder presentation. (c) A MULT VI60 VI60 schedule programmed on the right-hand key, upon which a triangle and a circle alternated.

The concurrent-chains procedure is diagrammed in Figure 2. The experimental procedure in detail was as follows: In the initial links, the colour on the left-hand response (R) key alternated between red and green following each peck on the centre changeover (CO) key, which remained white. The right-hand key was not illuminated during the initial links. Responses on the R key when it was red initiated the concurrent terminal link according to a VI60 schedule. Responses on the R key when it was green initiated the mixed concurrent terminal link, also according to a VI60 schedule. The above conditions applied for two birds, while key light conditions were reversed for the other two birds. All VI tapes were made using the Segal (1964) technique.

During the initial few sessions, it was found that in spite of the fact that concurrent VI 60 schedules were programmed in the initial links, the entries into the terminal links were not equal. Since this inequality of relative entries seemed likely to cause a preference for the terminal link entered more often, a procedure similar to that used by Stubbs and Pliskoff (1969) was introduced. Whenever one tape drive assigned a terminal link entry, both VI tape drives were halted. The terminal link entry was produced by the next response on the R key in the presence of

Figure 2. The concurrent-chains procedure. In the initial links, responses on the R key produced a terminal link according to concurrent VI 60 sec. schedules. During each terminal link, responses on the R key produced food according to two concurrent VI schedules. In the concurrent terminal link, separate stimuli were correlated with the two schedules, while in the mixed concurrent terminal link, the stimuli were not reliably correlated with the two schedules. 50% of the time the stimuli were correlated with the same schedules as in the terminal link; the rest of the time the stimuli were correlated with the opposite schedules to those in the concurrent terminal link.



Initial link conditions were reinstated following food presentation.

the appropriate stimulus and resulted in either a) exposure to the concurrent terminal link, or b) exposure to the mixed-concurrent terminal link. When a terminal link was entered, the left-hand key was no longer illuminated.

In the presence of the concurrent terminal link, the centre changeover (CO) key had a white horizontal line on a black background for Birds P-2 and P-4 (and a white vertical line on a black background for Birds P-1 and P-3). Responses on the CO key alternated the stimuli and schedules of reinforcement on the R key. For all 4 birds, the right-hand response (R) key had a white inverted triangle on a black background in the presence of the VI 60 sec. schedule and a white circle on a black background in the presence of the other concurrent schedule. The latter schedule was varied through the following range in different conditions of the experiment: EXT, VI 180 sec., VI 60 sec., VI 20 sec. Responses on this key occasionally produced 4 seconds' access to food, except for Bird P-3, for whom the feeder presentation was of 3 seconds' duration. Following food presentation, the initial link was reinstated.

In the presence of the mixed-concurrent terminal link, the CO key had either a white horizontal or vertical line on a black background. When the CO key stimulus was a horizontal line in the presence of the concurrent terminal link, it was a vertical line in the presence of the mixed-concurrent terminal link and vice-versa. Responses on the CO key alternated the stimuli and schedules of reinforcement on the R key. The stimuli, however were not correlated with the schedules of reinforcement. Appro-

ximately 50% of the time throughout the course of the experiment, the stimulus-schedule relationship in the mixed-concurrent terminal link was the same as that in the concurrent schedule of reinforcement; the rest of the time this relationship was the opposite. When a terminal link entry occurred, either stimulus and either schedule was equally likely to be present. During the mixed-concurrent terminal link, responses on the R key produced access to food on the same schedules of reinforcement as in the concurrent terminal link. Following food presentation, the initial link was reinstated.

In the initial links, changeovers produced a minimum delay before entry into the terminal links. In the terminal links, changeovers produced the same minimum delay before reinforcement was possible. This minimum time is called the changeover delay (COD) and was always 2 seconds in duration. If an entry into a terminal link or a reinforcer was set up during this delay, it remained set up until delivered.

A procedure similar to the Stubbs and Pliskoff (1969) procedure was used in the terminal links as well as the initial links to guarantee a specified relative rate of reinforcement for each schedule. This involved the halting of both VI tape drives when either assigned a reinforcer. This is unlike the usual procedure of concurrent schedules in that reinforcement is not scheduled independently for each response class.

The concurrent schedules in the terminal links were unequal VI schedules. The two schedules were chosen to produce relative distributions of reinforcers (expression 4) of .25, .50, .75, and

1.00; one schedule was always VI 60 sec and the value of the other schedule is shown in Table 1. For two birds, responding in the presence of red in the initial link produced the concurrent terminal link and responding in the presence of green in the initial link produced the mixed-concurrent terminal link. The colour conditions were reversed for the other pair of birds. The stimulus on the CO key was a vertical line for two of the birds and a horizontal line for the other two birds.

Sessions were conducted seven days a week except for rare equipment breakdowns and illnesses of the experimenter. Sessions were terminated following 60 reinforcements, after which all the chamber lights were extinguished and the keys were inoperative. As in the Hursh and Fantino (1974) study, each condition was in effect for at least 18 sessions and was terminated when the distribution of responding and time in the initial links and all of the six terminal link measures met a day-to-day stability criterion applied to the last nine sessions: the nine sessions were divided into three groups of three sessions each and the mean of the three choice proportions in each group was determined. To satisfy the stability criterion, the group means (M_1, M_2, and M_3) could not span a range greater than 5% (.05) and the means could not show a consistent increasing or decreasing trend ($M_1 < M_2 < M_3$ or $M_1 > M_2 > M_3$). When the data of three of the four birds had not satisfied the stability criterion after 125 sessions in the initial phase of the experiment, the stability criterion was made slightly less stringent: both choice measures in the initial links had to satisfy the requirements and only

Table 1. Summary of experimental procedure.

Phase	Component correlated with ▽ in concurrent terminal link	Component correlated with ○ in concurrent terminal link	Relative Reinforcement Rate
1.	VI 60 sec.	VI 180 sec.	0.75
2.	VI 60 sec.	EXT	1.00
3.	VI 60 sec.	VI 20 sec.	0.25
4.	VI 60 sec.	VI 60 sec.	0.50
5.	CONC VI 60 VI 60 and EXT in terminal links		

Subject	Colour of initial link R key when pecks produced concurrent terminal link	Colour of initial link R key when pecks produced concurrent terminal link	CO key stimulus in concurrent terminal link	CO key stimulus in mixed-concurrent terminal link
P-1	Green	Red	|	—
P-2	Red	Green	—	|
P-3	Red	Green	|	—
P-4	Green	Red	—	|

Subject	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
P-1	143	18	72	20	20
P-2	127	29	35	31	10
P-3	150	75	18	75	20
P-4	114	67	39	22	20

Number of sessions per phase for each subject.

five of the six terminal link measures had to satisfy them. The maximum number of sessions allowed in the initial phase of the experiment was 150. Subsequently, a maximum of 75 sessions was allowed for all birds before the next phase was introduced. At least 18 sessions were programmed following any adjustment to the experimental conditions, such as the change of reinforcement duration from 4 seconds to 3 seconds for Bird P-3 during the initial phase.

Data was collected in order to calculate the following measures: 1) changeover rate in the initial links; 2) relative local response rate in the initial links (see expression 3); 3) relative overall response rate in each initial link (see expression 1); 4) relative time in each initial link (see expression 2); 5) relative rate of entry into each terminal link; 6) changeover rate in each terminal link; 7) relative local response rate in each terminal link; 8) relative overall response rate in each component of each terminal link; 9) relative time in each component of each terminal link. Measures 7, 8, and 9 could be calculated for the concurrent terminal link, the mixed-concurrent terminal link with regard to schedules, or the mixed-concurrent terminal link with regard to stimuli. For instance, it was possible to calculate both the relative amount of time a bird spent in the presence of the VI 60 sec. schedule in the mixed-concurrent terminal link as well as the relative amount of time the bird spent in the presence of the triangle. These measures would be identical in the concurrent terminal link, since the stimuli were correlated with the schedules of

reinforcement.

Since, as will be seen in the results section, no exceptionally strong preferences were discovered for either terminal link in any of the experimental conditions, extinction schedules were introduced in the non-preferred terminal links for three of the birds and in the preferred terminal link for one bird to test the sensitivity of the procedure to changes in the terminal links.

RESULTS

Mean relative responding in the initial links during the final six sessions in each condition is shown for each bird in Figure 3. Relative responding in the initial links is a measure of preference for the concurrent terminal links. Mean relative time in the initial links for the same sessions is shown in Figure 4. Relative time in the initial links is another measure of preference for the concurrent terminal links. The horizontal lines at .50 represent indifference. Points above the 0.50 line indicate preference for the concurrent terminal link; points below the 0.50 line represent preference for the mixed-concurrent terminal link. As can be seen in Figures 3 and 4, all birds but one (P-3) consistently preferred one terminal link or the other. However, this preference was evident even when the two terminal links were equivalent; that is, when CONC VI 60 VI 60 and MIX-CONC VI 60 VI 60 were programmed in the terminal links (.50 on x-axis, Figures 3 and 4). With these schedules, there was essentially no difference between the terminal links since reinforcements occurred equally often in the presence of the triangle and circle. These results suggest that some variable other than the terminal link schedules was controlling the performance in the initial links. Of the three birds showing a consistent terminal link preference, Birds P-1 and P-2 responded more and spent more time in the initial link leading to the

Figure 3. Relative response rate in the initial link leading to the concurrent terminal link as a function of the relative rate of reinforcement in the concurrent terminal link. The points are derived from responses during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time the experimental conditions were changed.

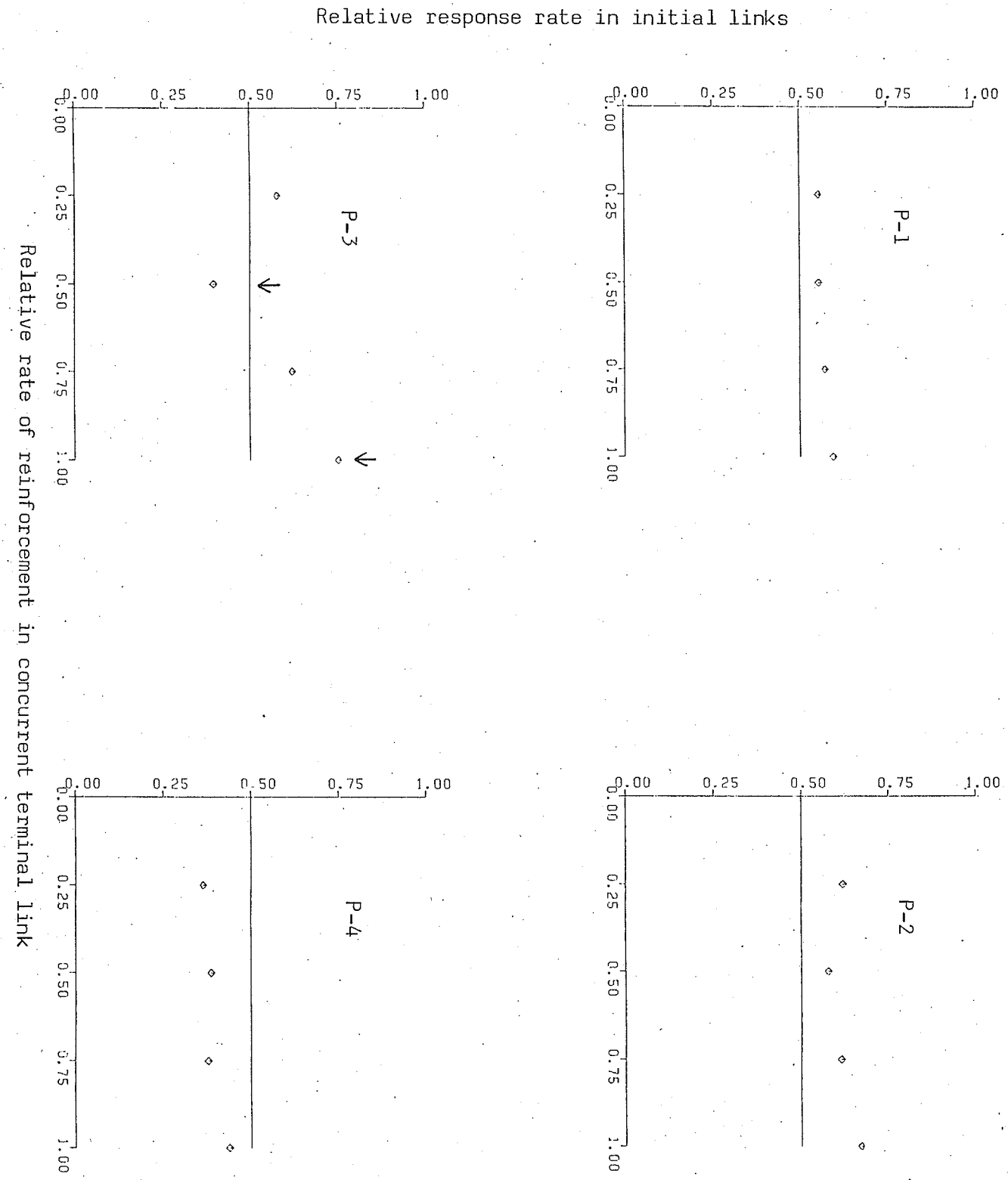
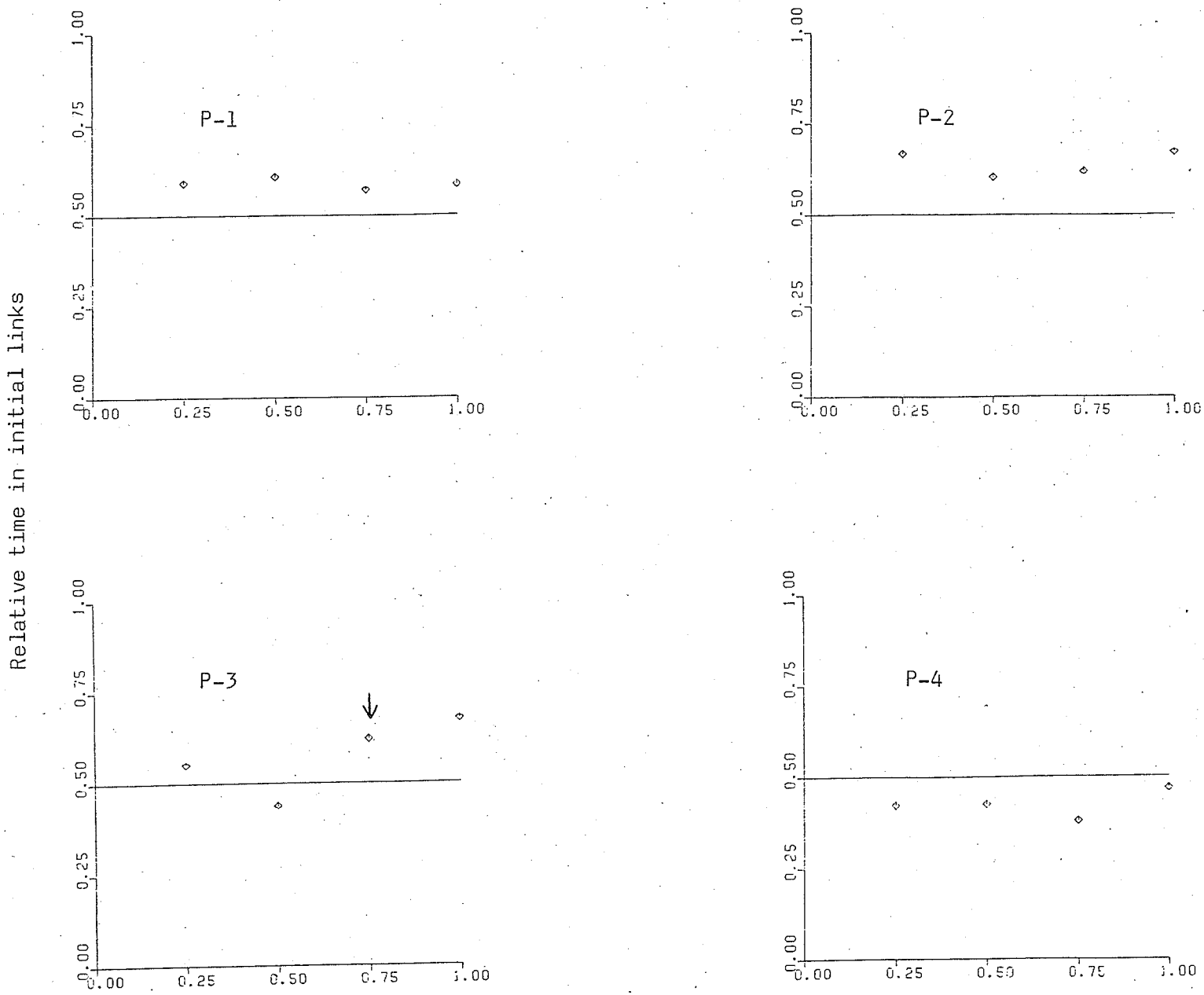

Relative response rate in initial links
Relative rate of reinforcement in concurrent terminal link
P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00

Figure 4. Relative time in the initial link leading to the concurrent terminal link as a function to the relative rate of reinforcemnt in the concurrent terminal link. The points are derived from data collected during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time the experimental conditions were changed.


P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
Relative time in initial links
Relative rate of reinforcement in concurrent terminal link

concurrent terminal link and Bird P-4 responded more and spent more time in the initial link leading to the mixed-concurrent terminal link. The fact that relative response rates and relative times did not equal .50 when the terminal links were equivalent would seem to indicate a colour bias was operating. Relative response rates and relative times above 0.50 for Birds P-2 and P-3 represent a larger proportion of initial link responses being emitted and time being spent in the presence of red than green; relative response rates above 0.50 for Birds P-1 and P-4 represent a larger proportion of initial link responses being emitted in the presence of green than red. An analysis of the initial link responding strictly in terms of colour reveals that Bird P-1 responded more and spent more time in the presence of green, Birds P-2 and P-4 responded more and spent more time in the presence of red, and Bird P-3 responded more and spent more time in the presence of green when the terminal-link schedules were equivalent, but in the presence of red when they were not equivalent.

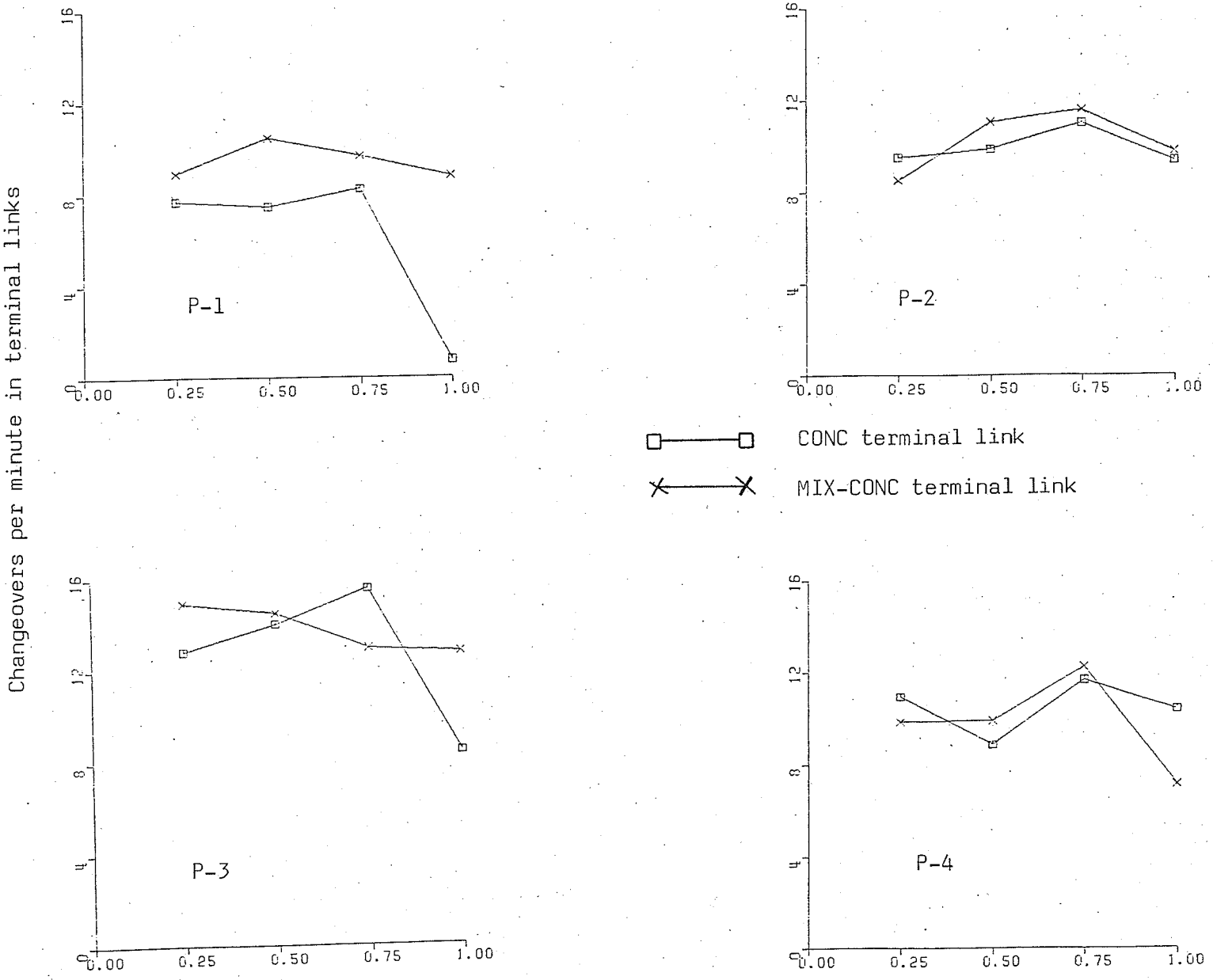
The data of Bird P-3 suggest that initial link responses and time may have been under the control of the terminal link schedules except when they were equivalent, at which time the key colour was the variable which controlled initial link responding.

In spite of the apparent bias induced by the initial link key colour, there seems to be a small tendency for a preference for standard concurrent schedules to occur, especially when the differences between the standard concurrent terminal link and the mixed-concurrent terminal link were large; i.e. when the rela-

tive rate of reinforcement was equal to 1.0 in the concurrent terminal link. This tendency is fairly clear for Birds P-2 and P-3, but unclear or absent for the other two subjects, although for all subjects, the highest relative responding in the initial link leading to the concurrent terminal link occurred when the relative rate of reinforcement was equal to 1.0.

Figure 5 shows the changeover rates in the terminal links as a function of the relative reinforcement rate in the terminal links for each bird. Data were averaged over the final six sessions in each condition. In most instances, the changeover rate was higher in the mixed-concurrent terminal link than in the concurrent terminal link, although this pattern is completely consistent for Bird P-1 only. For all birds, the changeover rates were higher in the concurrent terminal link when the relative rate of reinforcement was equal to 0.75 than when it was equal to 0.25, 0.50, or 1.0. For Birds P-1 and P-3, the changeover rate dropped dramatically in the concurrent terminal link when the relative rate of reinforcement was equal to 1.0. Bird P-1 almost stopped changing over altogether. This effect did not occur with the other two birds; in the case of Bird P-4 the opposite effect is evident: the changeover rate dropped in the mixed-concurrent terminal link rather than the concurrent terminal link. The fact that changeover rate does not go to 0.0 when the relative rate of reinforcement rate is equal to 1.0 may indicate that supersticious changeovers are occurring. That is, the changeover responses of the birds may have been maintained by

Figure 5. Changeover rate in the terminal links as a function of the relative rate of reinforcement. The points are derived from responses during the final six sessions of each experimental condition.


Changeovers per minute in terminal links
P-1
P-2
P-3
P-4
0
4
8
12
16
0.00
0.25
0.50
0.75
1.00
CONC terminal link
MIX-CONC terminal link
Relative rate of reinforcement in concurrent terminal link

the occasional presentation of food following a changeover and a response on the R key. This may have been eliminated by a longer COD.

Figure 6 shows the relation between relative overall response rate and relative rate of reinforcement in the concurrent terminal link during the final six sessions in each condition for each bird. Figure 7 shows the relation between relative time and relative rate of reinforcement in the concurrent terminal link for the same sessions. Perfect matching is represented by the diagonal line with a slope of 1.0. The lines with a slope of less than 1.0 were obtained from a least squares linear regression analysis. The equations for these lines appear in each figure. As can be seen in Figure 6, there was a tendency for relative overall response rate to match the relative rate of reinforcement. Although the preference for the condition providing the greater proportion of reinforcement is less extreme than the matching relation would predict (i.e. "undermatching" is present), the distribution of responses has come under the control of the reinforcement distribution to a considerable extent. As can be seen in Figure 7, there was less of a tendency for relative time to match the relative rate of reinforcement than in the case of relative rate of reinforcement. It appears that the relative time distribution has not come under the control of the reinforcement distribution to the same extent as the response distribution.

Mean relative responding in the presence of the VI 60 sec. schedule as a function of relative rate of reinforcement for that

Figure 6. Relative response rate in the concurrent terminal link as a function of the relative rate of reinforcement. The points are derived from data collected during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time that the experimental conditions were changed. Perfect matching is represented by the diagonal lines with a slope of 1.0. The lines with a slope of less than 1.0 were obtained from a least squares linear regression analysis. The equations for the lines are shown in the figures.

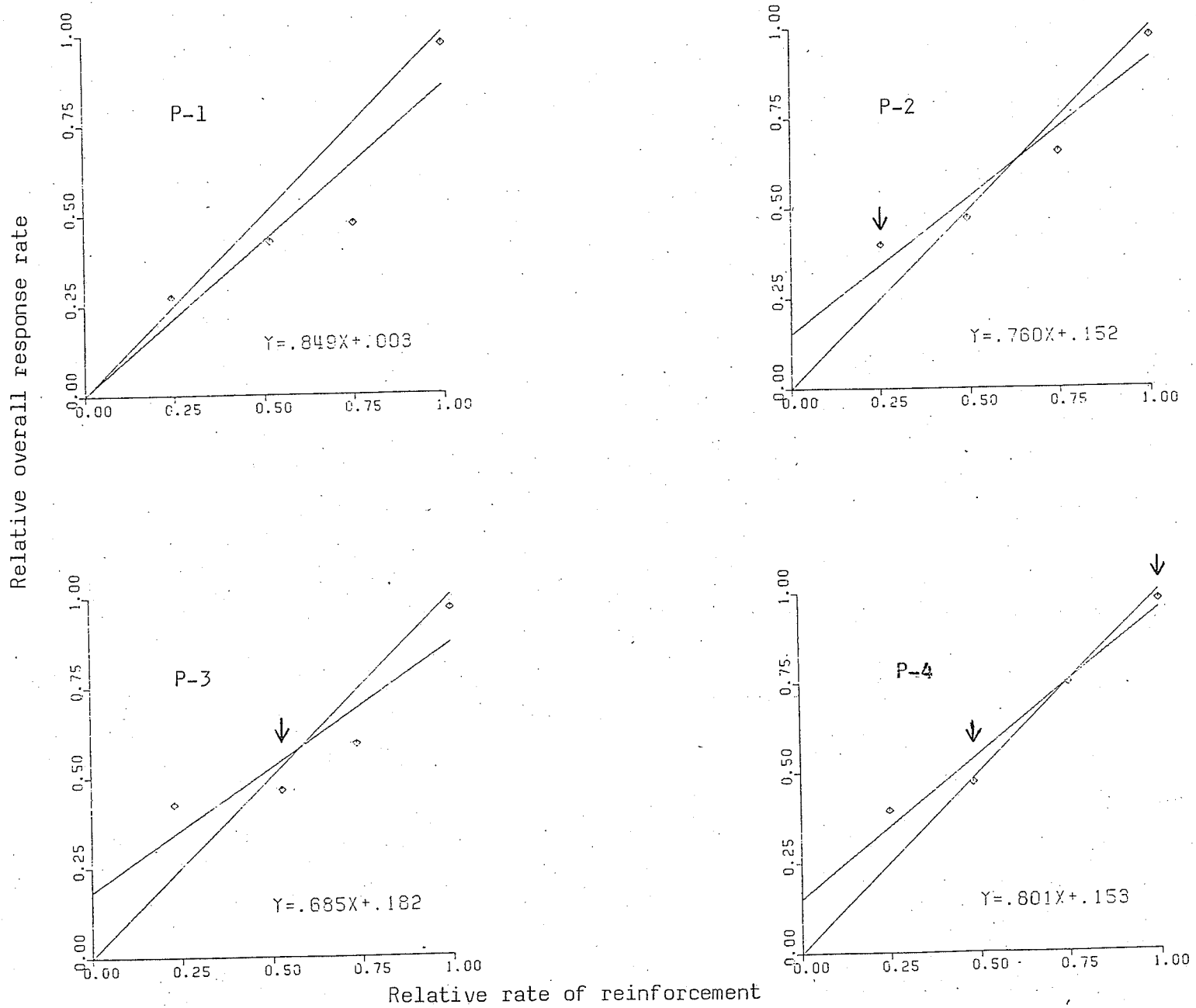
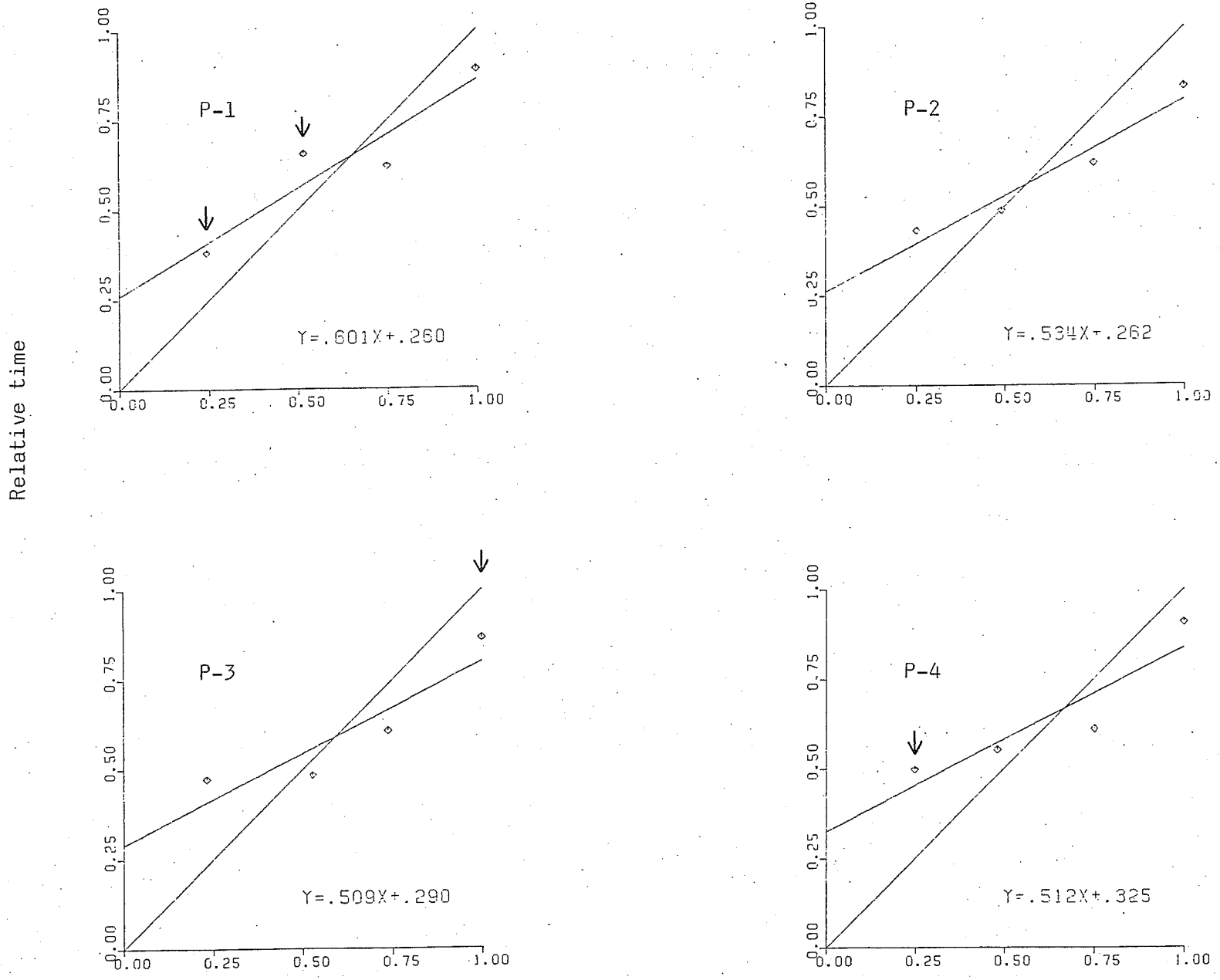

Relative overall response rate
P-1
Y=.849X+.003
P-2
Y=.760X+.152
P-3
Y=.685X+.182
P-4
Y=.801X+.153
0.00
0.25
0.50
0.75
1.00
Relative rate of reinforcement

Figure 7. Relative time in the concurrent terminal link as a function of the relative rate of reinforcement. The points are derived from data collected during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time that the experimental conditions were changed.


P-1
Y=.601X+.260
P-2
Y=.534X+.262
P-3
Y=.509X+.290
P-4
Y=.512X+.325
0.00
0.25
0.50
0.75
1.00
Relative time
Relative rate of reinforcement

schedule during the final six sessions in each condition is shown for each bird in Figure 8. The horizontal line at 0.50 represents equal responding in the presence of both schedules. As can be seen in Figure 8, the birds tended to respond equally often in the presence of each schedule of reinforcement in spite of the fact that the relative rate of reinforcement for the VI 60 sec. schedule ranged from 0.25 to 1.00. A comparison of Figures 6 and 8 reveals that while the relative response rate in the concurrent terminal link tended towards matching, the relative response rate in the mixed concurrent terminal link shows no tendency towards anything but equal responding in both schedules. This indicates that failure to observe strong preferences for concurrent versus mixed-concurrent terminal links (Figures 3 and 4) were not due to a failure to obtain differential control over the behaviour in the terminal links. Indeed, each schedule in the terminal links exerted control similar to that which would have been observed had the terminal link schedules been studied in isolation.

Mean relative time spent in the presence of the VI 60 sec. schedule as a function of the relative rate of reinforcement for that schedule during the final six sessions in each condition is shown for each bird in Figure 9. The horizontal line at 0.50 represents equal time spent in the presence of each schedule. As can be seen in Figure 9, the birds tended to spend equal amounts of time in the presence of both schedules of reinforcement, in spite of the fact that the relative rate of reinforcement for the VI 60 sec. schedule ranged from 0.25 to 1.00. A comparison of

Figure 8. Relative response rate in the presence of the VI 60 schedule in the mixed-concurrent terminal link as a function of the relative rate of reinforcement. The points are derived from data collected during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time the experimental conditions were changed.

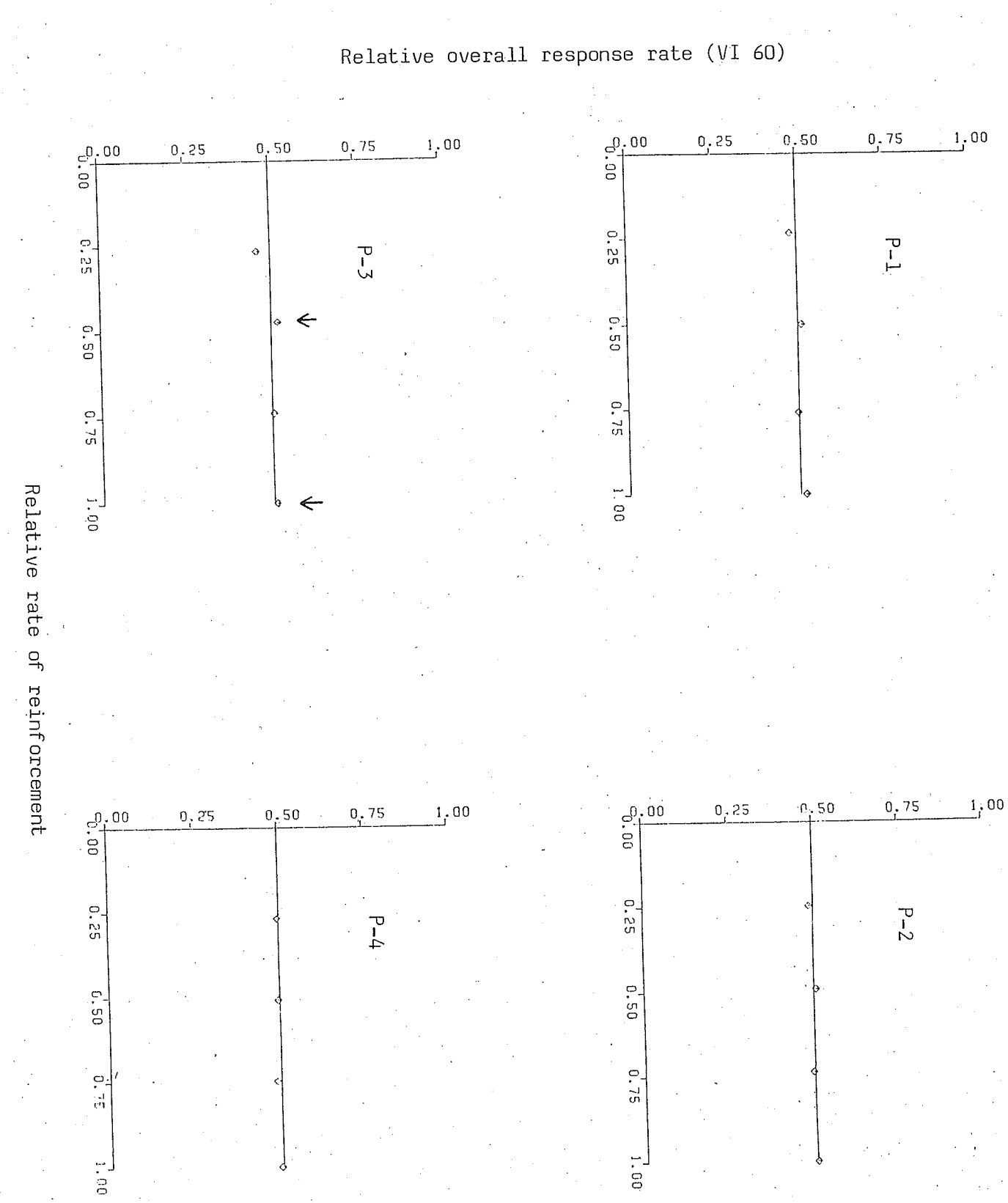
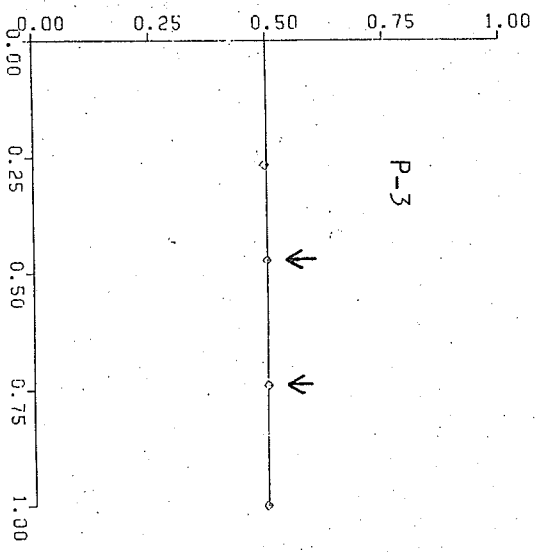
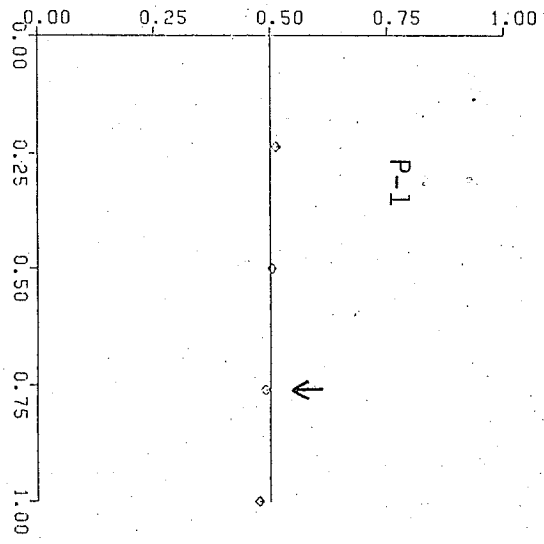
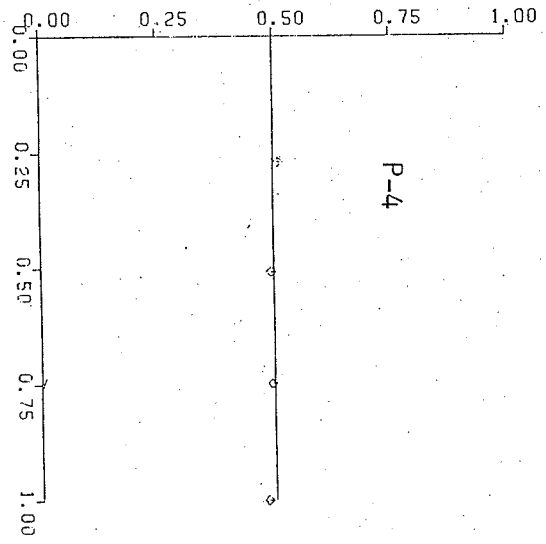

Relative overall response rate (VI 60)
Relative rate of reinforcement
0.00
0.25
0.50
0.75
1.00
P-1
P-2
P-3
P-4

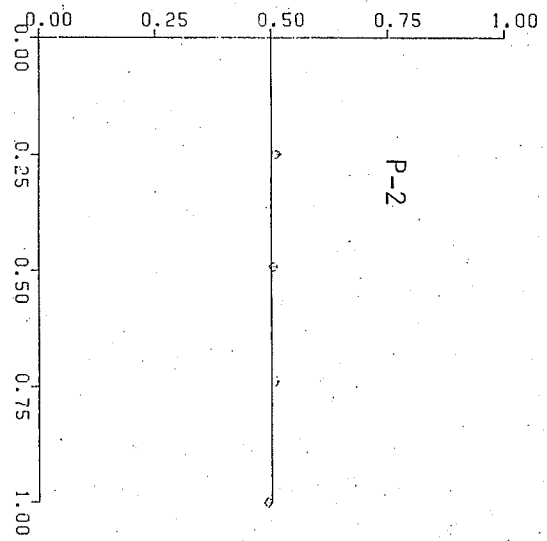
Figure 9. Relative time in the presence of the VI 60 schedule in the mixed-concurrent terminal link as a function of the relative rate of reinforcement. The points are derived from data collected during the final six sessions of each condition. Arrows indicate points derived from data which did not satisfy the stability criterion at the time the experimental conditions were changed.

Relative time (VI 60)









A comparison of Figures 8 and 9 will reveal that the response data and time data are comparable. A comparison of Figures 7 and 9 will reveal that while the relative time in the concurrent terminal link tended somewhat towards matching the relative rate of reinforcement, the relative time in the mixed-concurrent terminal link did not tend towards anything but equal time spent in the presence of each schedule.

The mean relative overall response rate in the presence of the triangle during the final six sessions in each condition is shown for each bird in Figure 10. Mean relative time is shown for the same sessions in Figure 11. The horizontal line at 0.50 represents equal responding in the presence of the triangle and the circle. Relative reinforcement rate is usually close to 0.50 although relative responding tends to vary on both sides of the 0.50 line for Subjects P-2 and P-4 and remain below the line for Subjects P-1 and P-3. Relative time tends to vary on either side of the 0.50 line for all birds except Bird P-3.

Figure 12 shows the relative response rate in the presence of the triangle in the mixed-concurrent terminal link as a function of the relative rate of reinforcement in the concurrent terminal link during the final six sessions in each condition for each bird. Figure 13 shows the relative time for the same sessions. The horizontal lines at 0.50 represent equal responding and equal time spent in the presence of the triangle and circle. As can be seen in Figures 12 and 13, the relative responding and relative time spent in the presence of triangle in the mixed-concurrent terminal link did not seem to be determined

Figure 10. Relative response rate in the presence of the triangle in the mixed-concurrent terminal link as a function of the relative rate of reinforcement. The points are derived from data collected during the final six sessions in each condition. Arrows indicate points derived from data which did not satisfy the stability criterion when the experimental conditions were changed.

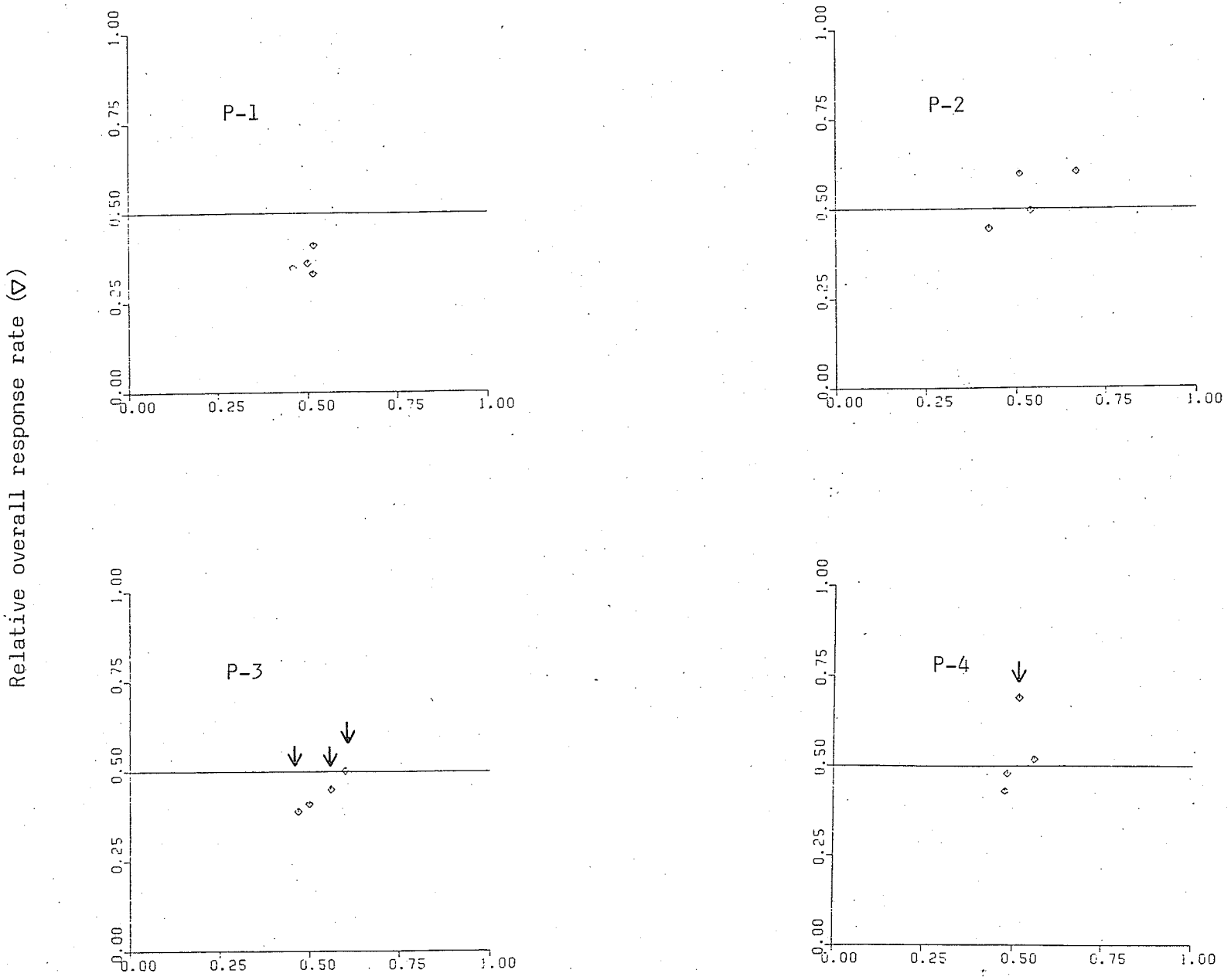

P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
Relative overall response rate (∇)
Relative rate of reinforcement

Figure 11. Relative time in the presence of the triangle in the mixed-concurrent terminal link as a function of relative rate of reinforcement. The points are derived from data collected during the final six sessions in each condition. Arrows indicate points derived from data which did not satisfy the stability criterion when the experimental conditions were changed.

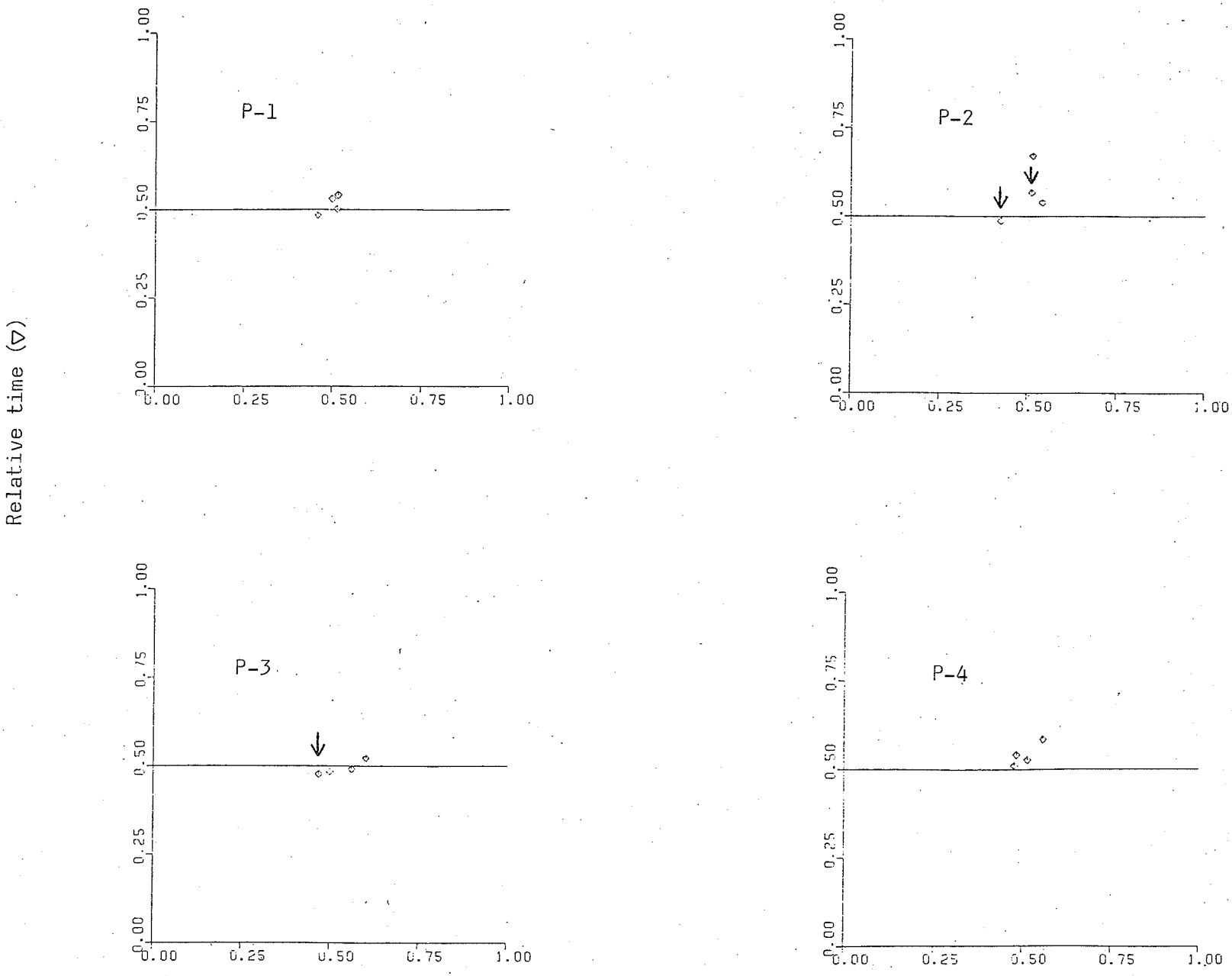

P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
Relative time (▽)
Relative rate of reinforcement

Figure 12. Relative response rate in the presence of the triangle in the mixed-concurrent terminal link as a function of the relative rate of reinforcement in the concurrent terminal link. The points are derived from data collected during the final six sessions in each condition. Arrows indicate points derived from data which did not satisfy the stability criterion when the experimental conditions were changed.

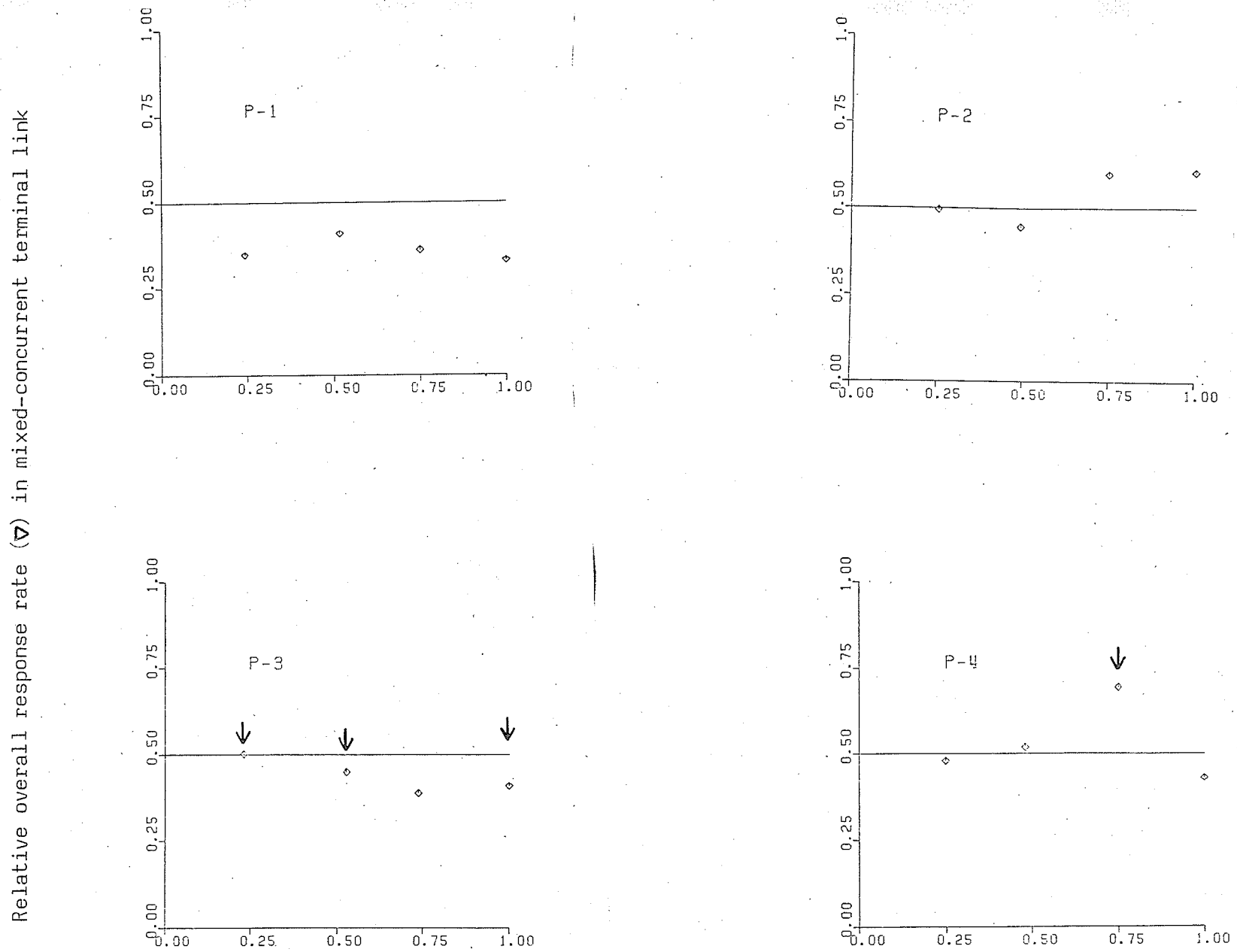
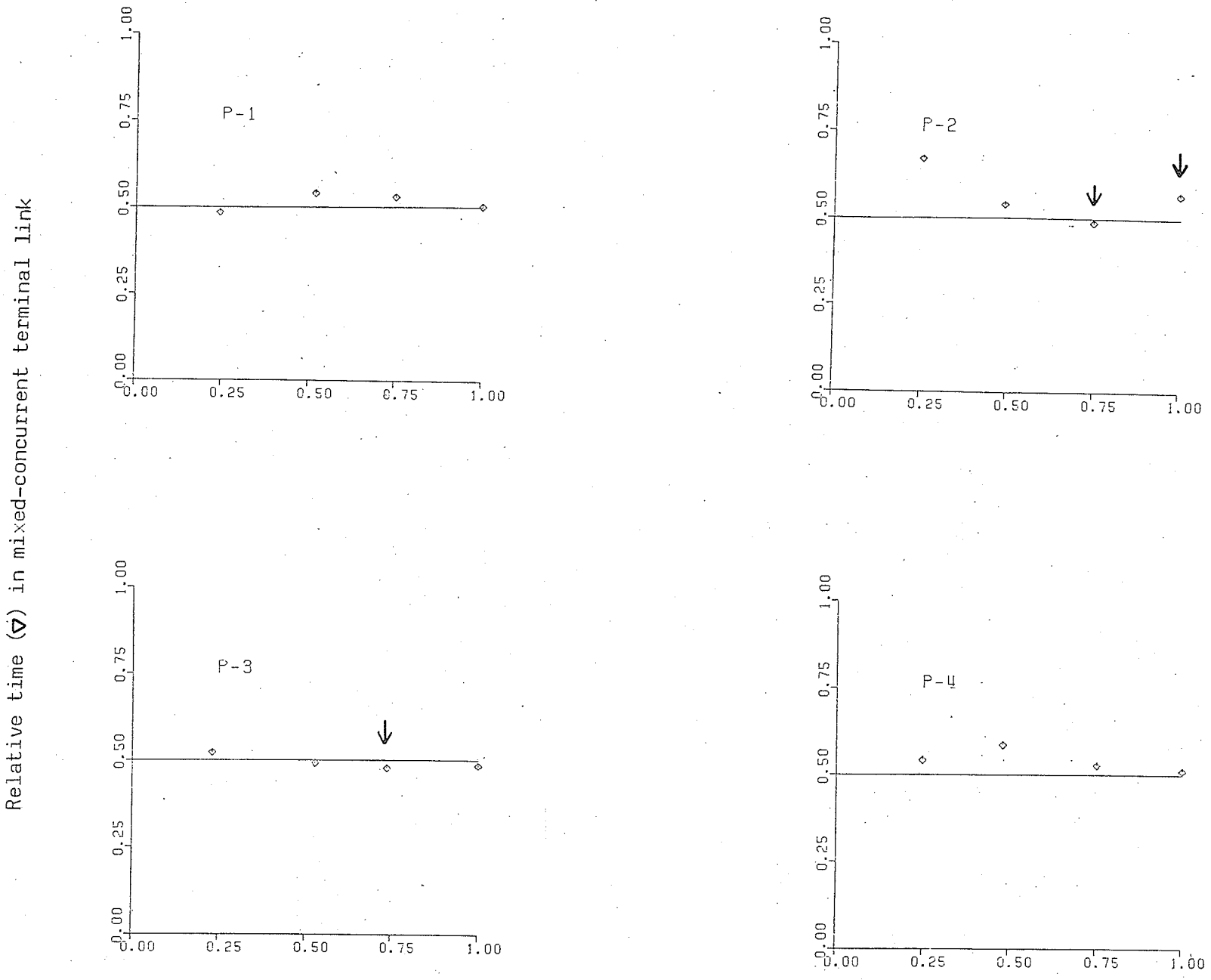

P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
Relative overall response rate (∇) in mixed-concurrent terminal link
Relative rate of reinforcement in concurrent terminal link

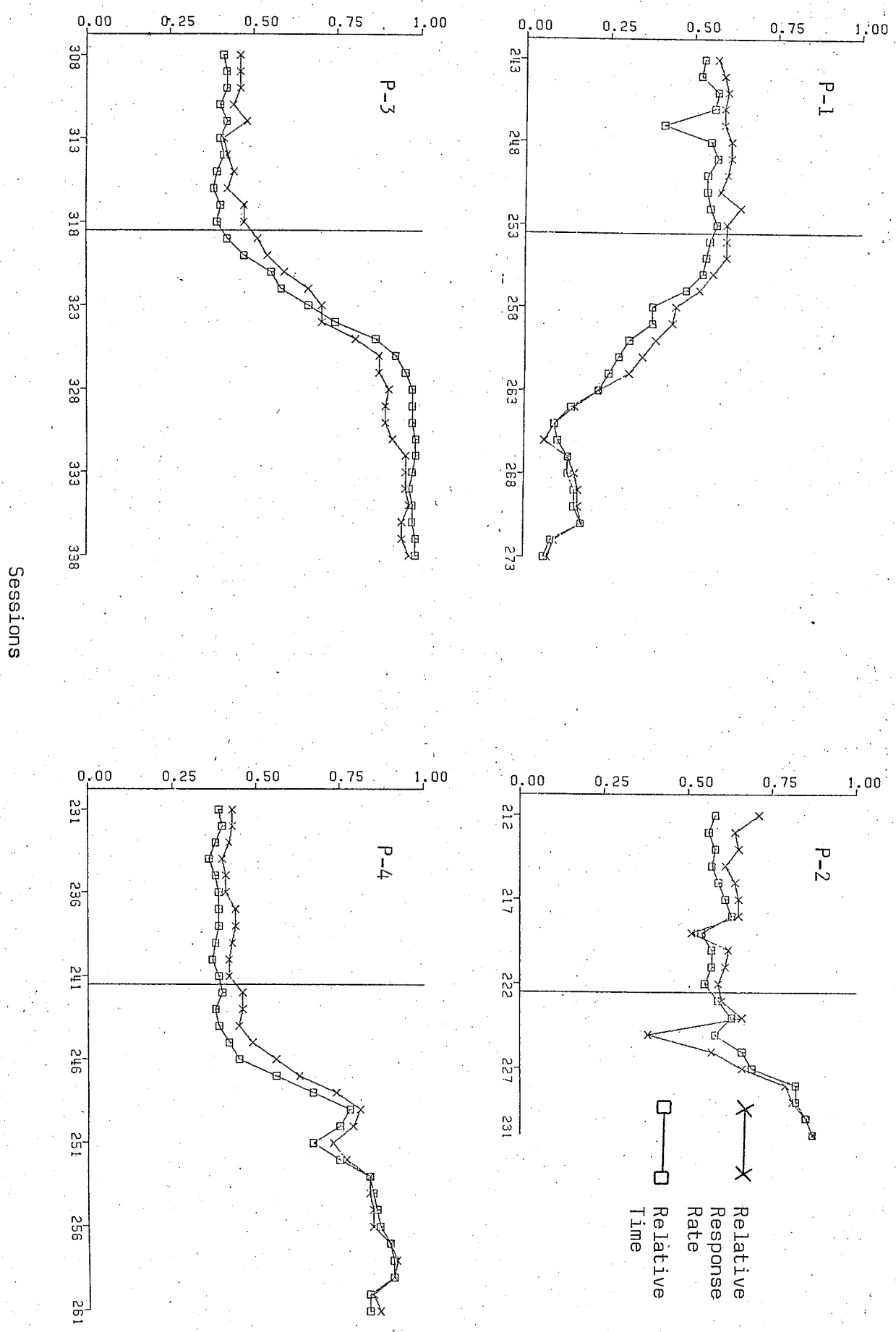
Figure 13. Relative time in the presence of the triangle in the mixed-concurent terminal link as a function of the relative rate of reinforcement in the concurrent terminal link. The points are derived from data collected during the final six sessions in each condition. Arrows indicate points derived from data which did not satisfy the stability criterion when the experimental conditions were changed.


P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
Relative time (∇) in mixed-concurrent terminal link
Relative rate of reinforcement in concurrent terminal link

by the relative rate of reinforcement in the presence of the triangle in the concurrent terminal link.

Figure 14 shows both the relative responding and relative time in the initial links for each bird during the final 11 sessions when CONC VI 60 VI 60 and MIX CONC VI 60 VI 60 (which are equivalent in terms of equal reinforcements being programmed in the presence of the triangle and circle for both terminal links) and during the remainder of the study when EXT was programmed in one of the terminal links. As can be seen in Figure 14, the programming of EXT in one of the terminal links had a dramatic effect on initial link preference, although the previous experimental manipulations generally had little effect on initial link behaviour. The data represented in Figure 14 show that the present procedure is indeed sensitive to terminal link changes.

Figure 14. Relative responding and relative time in the initial links during the final 11 sessions when CONC VI 60 VI 60 and MIX CONC VI 60 VI 60 were scheduled in the terminal links and during the remainder of the study when EXT was programmed in one of the terminal links.


Relative response rate and relative time initial links
P-1
P-2
P-3
P-4
0.00
0.25
0.50
0.75
1.00
213
248
253
258
263
268
273
212
217
222
227
231
308
313
318
323
328
333
338
231
236
241
246
251
256
261
Sessions
Relative Response Rate
Relative Time

DISCUSSION

As has been pointed out in the results section, two of the birds consistently preferred the concurrent terminal link and one bird consistently preferred the mixed-concurrent terminal link, while the data of the fourth bird was suggestive of a preference for the concurrent terminal link. The fact that substantial preferences were still evident when the terminal links were equivalent suggests that the data were being influenced largely by colour preferences (or some other variable producing what Baum, 1974, has termed "bias"). It seems logical to expect that the relative response rate and relative time in the initial links would be equal to .50 when the terminal links were equivalent if nothing but a schedule preference were determining initial link responding and time distribution. However, the relative response rate and relative time measures in the initial links never stabilized at a value close to 0.50 for any of the birds under these conditions. The presence of a colour preference in a concurrent-chains schedule has been noted by Hursh and Fantino (1974), who found that preferences can be as high as 76% when terminal link schedules are identical and terminal-link key colours are not identical. The preferences in the present study have been found under slightly different circumstances: the terminal-link key colours and schedules were identical and the initial-link key colours were different.

The present data suggest that at least some birds may prefer standard concurrent schedules to mixed-concurrent schedules. This preference is evident in the data for Birds P-2 and P-3. The preference seems slight, however and easily obscured by other variables, such as key colour, producing what Baum (1974) refers to as "bias", or a preference which exists when apparent equality of reinforcement would predict indifference. The data of Birds P-2 and P-3 suggest the algebraic addition of a colour preference and a schedule preference.

The initial link responding in the present study appeared to have been primarily controlled by the equal terminal link schedules of primary reinforcement with a slight preference apparently produced by the initial link key colours. The terminal link responding came under the control of the terminal link variables. Any question as to the sensitivity of the procedure to changes in the terminal link conditions was soon dispelled when EXT was programmed in one of the terminal links for each bird. Dramatic changes in initial link preferences appeared quickly.

Fantino (1977) has pointed out that the preference which has typically been found for multiple schedules over mixed schedules programmed in terminal links of concurrent-chains schedules can perhaps be explained in terms of the common finding that the presence of short inter-reinforcement intervals has a disproportionate influence on choice (Davison, 1969, 1972; Fantino, 1967; Herrnstein, 1964b; Hursh and Fantino, 1973; Killeen, 1968; Navarick and Fantino, 1975). In the case of multiple schedules,

stimuli correlated with the shorter delay to reinforcement occur at the beginning of the terminal link on half the trials. This never occurs in the terminal link containing the mixed schedule, since a separate stimulus is constantly present during both components of the mixed schedule. Therefore, the appearance of the stimulus correlated with the shorter delay to reinforcement occurs in one terminal link and not the other, and the former terminal link is preferred. The present study did not follow the usual procedure of programming two separate stimuli in the multiple-type (concurrent) terminal link and a separate single stimulus in the mixed-type (mixed-concurrent) terminal link. Instead, equal exposure to both stimuli was provided by having the stimuli used in the concurrent terminal link appear in the mixed-concurrent terminal link, although in such a fashion that the stimuli were not correlated with the separate component schedules. It was therefore impossible for stimuli correlated with a shorter delay to reinforcement to occur more often in one terminal link than the other and thereby influence preference, as Fantino suggests has been the case in comparisons of mixed and multiple schedules. Thus it is possible that the use of stimuli in the presence of mixed schedules would cause the preference for multiple schedules to disappear, although care would have to be taken that the stimuli were presented and changed in such a manner that they were not correlated with either component of the mixed schedule, and that the changes did not occur when the schedule changes occured.

The changes in changeover rates in the present study differ

from those found in studies of ordinary concurrent schedules. Stubbs and Pliskoff (1969) and Herrnstein (1961) have found that with a fixed COD duration, the changeover rate decreases as the relative frequency of reinforcement diverges from .50. Stevens (1972) found that with very few exceptions, the changeover rates of rats decreased as relative reinforcement rate diverged from either .25 or .50. There was no common point of divergence in the present study, although it was found that in the concurrent terminal link the CO rates were lower at other values of the relative reinforcement frequency than .75. Why this occurred is not clear. It seems logical to expect the changeover rates to be equal when the relative rate of reinforcement equals .25 and .75, since in both cases, one-fourth of the reinforcements are being assigned to one condition or the other. One might argue that the only real difference between a relative rate of reinforcement of .25 and .75 stems from the arbitrary choice of which schedules provide r_1 and r_2 in expression (4):

$$\frac{r_1}{r_1 + r_2}$$

However, there is another difference between the two relative rates of reinforcement in the present study: the schedule combinations and the absolute frequencies of reinforcement are different. When the relative rate of reinforcement was equal to .25, the concurrent schedules of reinforcement were VI 60 and VI 20. When the relative rate of reinforcement was equal to .75, the concurrent schedules of reinforcement were VI 60 and VI 180.

Possibly the changeover rates were lower when the relative rates of reinforcement were equal to .25 than .75 because the absolute rate of reinforcement was higher at the .25 value.

Bourland and Miller (1975a) found in comparing concurrent and "parallel" (mixed-concurrent) conditions, changeover frequency was higher in concurrent conditions. The present findings are generally the reverse; changeover frequency was usually higher in the mixed-concurrent terminal link. No consistent pattern was found in the Stevens (1972) study. Bourland and Miller suggest that the higher changeover frequency in the concurrent conditions of their study may have been due to the possibility of the stimulus change maintaining the response while no such stimulus change occurred in the "parallel" conditions and the changeover rate was therefore lower. In the present study, changeover responses in both terminal links produced a stimulus change, although in the case of the mixed-concurrent terminal link the stimuli were not reliably correlated with the separate schedules of reinforcement. This difference in changeover response consequences might account for the difference in findings in the present study and the Bourland and Miller study. It is also possible that the increases in overall reinforcer rate may have produced the decline in the changeover rate.

"Undermatching" (a weaker preference for the richer schedule than that predicted by matching and represented by a slope less than 1.0) and "bias" (unaccounted for preference, represented by a y intercept not equal to 0.0). are evident in the data collected from the concurrent terminal link (Figures 6 and 7).

The response data approximate matching more closely than do the time data. De Villiers (1977), in analyzing the data from seven experiments (Herrnstein, 1961; Catania, 1963b; Stubbs and Pliskoff, 1969; Silberberg and Fantino, 1970; Trevitt, Davison and Williams, 1972; Baum, 1972; McSweeney, 1975), found no systematic deviation from matching for time ratios, but for response ratios, the slopes of the individual regression lines tended towards undermatching with a median slope of .80. De Villiers points out that several methodological considerations should be taken into account in evaluating such data. He mentions such factors as prior exposure to schedules other than CONC VI VI schedules, order effects, and the role of the COD. The last factor is the most relevant to the interpretation of the present results. Studies by Brownstein and Pliskoff (1968), Herrnstein (1961), and Shull and Pliskoff (1967) have shown that a minimum COD duration is necessary for matching to be obtained. This minimum duration varies across birds; Brownstein and Pliskoff (1968), for example, found that values between 2 and 7.5 seconds were required to obtain matching for each of their three pigeons. De Villiers argues that it is not surprising that in most studies some subjects show regression lines with slopes less than 1.0 simply as a result of COD durations that are too short. It is possible that the 2 seconds' COD duration used in the present study was too short and contributed to the under-matching shown in Figures 6 and 7. It is also possible that supersticious changeovers were being emitted due to the brief length of the COD. This may have produced , or been involved in, the undermatching that was found.

Another factor which may possibly have contributed to undermatching in the present study concerns the reinforcement in the mixed-concurrent terminal link and its possible effects on responding in the concurrent terminal link. While the relative rate of reinforcement in the presence of the triangle and circle were programmed to vary through a range of values (0.25, 0.50, 0.75, and 1.0) in the concurrent terminal link, the birds were still receiving reinforcements in the presence of the two stimuli in the mixed-concurrent terminal link. This may have had the effect of causing the birds to respond more often in the presence of the stimuli in the concurrent terminal link than the matching formulation would predict, although the distribution of time and responses in the presence of the triangle and circle in the mixed-concurrent terminal link did not seem to be affected by the distribution of reinforcements in the presence of the triangle and circle in the concurrent terminal link, as shown by Figures 12 and 13. These results suggest that mixed-concurrent terminal link reinforcement might not have had the reverse effect on the concurrent terminal link performance measures.

The responding and distribution of time in the mixed-concurrent terminal links is typical of that found in mixed-concurrent situations, although response and time allocations have been found to approximate relative rate of reinforcement more closely when the absolute reinforcement frequency is high (Stevens, 1972; Bourland and Miller, 1975b). When no discriminative stimuli are correlated with concurrently available schedules of reinforcement, organisms tend to respond equally in the

presence of both schedules, and, according to the present findings, make more frequent changeovers between the schedules.

Responding in the presence of just the stimuli (i.e. responding in the presence of the triangle and circle) as well as responding in the presence of the component schedules in a mixed-type schedule has never been recorded previously, due to the fact that previous mixed-type schedules have generally been programmed with a single stimulus present throughout their duration. The use of separate stimuli which are not correlated with the separate schedules of reinforcement in the mixed-concurrent terminal link allows the experimenter to control for any possible reinforcing effect that stimulus change might have on the changeover response as well as any differential effects that terminal link stimuli might have on initial link responding. It also permits an analysis of response and time distributions in terms of the stimuli.

SUMMARY AND CONCLUSIONS

The present study has shown the extent to which different colours on the initial link response key can affect response and time distributions in a concurrent-chains schedule even when the terminal links are sufficiently different to control different performances. In spite of the apparent bias produced by the initial link key colours, the present study has shown that at least some birds appear to "prefer" standard concurrent schedules to mixed-concurrent schedules, especially when the differences between the two were large. It has also been shown that complex terminal links contained in an extremely complex concurrent-chains schedule can come to control performance in a fashion similar to that found when the terminal links are studied in isolation. A further finding has been that the use of stimuli in the presence of mixed-type schedules possibly tends to reduce somewhat the preference for simultaneously available multiple-type schedules and possibly tends to increase the changeover rate.

Further studies with concurrent and mixed-concurrent terminal links in concurrent-chains schedules could investigate preference by using shorter initial link schedules, which tend to provide a more sensitive measure of preference, in combination with the Stubbs and Pliskoff (1969) procedure to control for equal terminal link entries. The COD should be manipulated in future studies of this type to assess the effects on changeover rates in all links as well as response and time distributions in the concurrent terminal link.

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