

BEHAVIOUR MAINTAINED BY MIXED-CONCURRENT SCHEDULES OF REINFORCEMENT

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William H. Stevens

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DEDICATION

To the memory of David Stevens Marshall

June 30, 1937 - October 28, 1971

whose friendship will never be forgotten.

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ABSTRACT

Behaviour Maintained by Mixed-Concurrent Schedules of Reinforcement

by

William Stevens

Previous research has indicated that matching of relative performance measures and relative frequency of reinforcement is obtained under several different conditions when separate stimuli or separate operanda are correlated with each concurrent schedule of reinforcement. The purpose of this experiment was to determine whether or not the above situation was necessary for matching to be obtained.

Four rats, at 80% normal body weight were exposed to ascending and descending sequences of a range of concurrent variable-interval schedules with separate stimuli correlated with each schedule. Matching was obtained. Then three of the four subjects were exposed to the same sequences with no separate stimuli correlated with each schedule. Matching was not obtained, although it was approached when one of the subjects was exposed to concurrent schedules having a high frequency of reinforcement. The data appears to suggest that matching can be obtained in the absence of separate stimuli as long as the frequency of reinforcement is high enough in at least one schedule for the subject to discriminate between the two schedules.

CHAPTER I

INTRODUCTION

Ferster and Skinner (1957, p. 124) have defined concurrent operants as: "Two or more responses, of different topography at least with respect to locus, capable of being executed with little mutual interference at the same time or in rapid alternation, under the control of separate programming devices."

A great deal of research has been performed to investigate the exact nature of the interactions between concurrent operants and their schedules of reinforcement. In order to isolate the relevant factors pertaining to these interactions, it has been necessary for investigators to develop different methods for programming concurrent schedules of reinforcement. Most, if not all, of the methods developed are variations of two standard procedures.

In the two-key procedure, the organism has access to two or more 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 a second operandum (Findley, 1958).

Catania (1966) points out that the two procedures are equivalent when the concurrent responses can occur only successively and not

simultaneously since in both procedures each of the concurrent schedules of reinforcement operates continuously. The only difference between the procedures is in the type of response required to switch from one schedule to the other. However, 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.

Much of the research that has been performed to investigate concurrent operants has dealt with the manner in which organisms (particularly pigeons) distribute their responses between or among the concurrent schedules of reinforcement. The dependent variables which have attracted the most attention 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:

$$\frac{R_a}{R_a + R_b}$$

where R_a and R_b are response rates for operants a and b 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:

$$\frac{T_a}{T_a + T_b}$$

where T_a and T_b are the amounts of time spent responding in the presence of stimulus a and stimulus b respectively;

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

$$\frac{R_a/T_a}{R_a/T_a + R_b/T_b}$$

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

Equations (2) and (3) apply only to instances where the CO-key procedure is used, since it is impossible to measure the time spent responding in the presence of each schedule when the two-key procedure is used.

Under certain conditions, which will be discussed below, it has been found that a "matching relationship" exists between relative response rate, relative time, and relative reinforcement rate. 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 calculated as follows:

(4)

$$\frac{r_a}{r_a + r_b}$$

where r_a and r_b are the number of reinforcements produced by operants a and b respectively.

An example will serve to demonstrate the matching relationship:

Let us assume a pigeon pecks a key in the presence of a red light (stimulus a) and a green light (stimulus b) for grain reinforcement. Any pecks occurring on a second key alternate the stimuli. We can record the numbers of responses occurring in the presence of each stimulus, the reinforcements in the presence of each stimulus, and the time spent in the presence of each stimulus. After one hour, we might obtain the following data:

Responses in the presence of stimulus a:	750
Responses in the presence of stimulus b:	250
Time spent in the presence of stimulus a:	2700 seconds
Time spent in the presence of stimulus b:	900 seconds
Reinforcements during stimulus a:	75
Reinforcements during stimulus b:	25

From the above data, we can calculate our relative measures.

Relative overall response rate equals:

$$\frac{R_a}{R_a + R_b} = \frac{750}{750 + 250} = \frac{750}{1000} = .75$$

Relative time equals:

$$\frac{T_a}{T_a + T_b} = \frac{2700}{2700 + 900} = \frac{2700}{3600} = .75$$

Relative local response rate equals:

$$\frac{R_a/T_a}{R_a/T_a + R_b/T_b} = \frac{750 / 2700}{750 / 2700 + 250 / 900} = \frac{2.78}{2.78 + 2.78} = .50$$

Relative reinforcement rate equals:

$$\frac{r_a}{r_a + r_b} = \frac{75}{75 + 25} = \frac{75}{100} = .75$$

The example shows the matching relationship existing between relative response rate, relative time, and relative reinforcement rate, all of which are equal to .75.

When the matching relationships between (1) relative response rate and relative reinforcement rate and (2) relative time and relative reinforcement rate do exist, the relative local response rate necessarily approximates 0.50, which is the case in the above example.

The above dependent variables have been investigated with a number of independent variables, such as (1) presence and duration of a change-over delay; (2) reinforcement programmed independent of the subjects' behaviour, (3) magnitude of reinforcement; (4) delay of reinforcement; and (5) force requirement of the operandum.

Before a statement of the current problem of investigation, some of the results obtained with concurrent variable-interval schedules of reinforcement will be briefly reviewed.

CHAPTER II

REVIEW OF THE LITERATURE

Herrnstein (1961), using pigeons as subjects and the two-key procedure, found that the matching function between relative overall response rate and relative reinforcement rate is obtained only when a changeover delay (COD) is employed. The COD was 1.5 seconds in Herrnstein's experiment.

The COD specifies the minimum time during which reinforcement is unavailable after a changeover from responding on one key to responding on the other. For example, if a pigeon is pecking the left of two keys and a reinforcement becomes available on the right key, the pigeon would have to peck the right key once to initiate the COD interval and again at the end of the interval to obtain reinforcement. If any intervening responses had been made on the left key before reinforcement had been obtained on the right one, the COD interval would have to be reinitiated on the right key.

When the CO-key procedure is used, the COD interval is timed from a response on the CO key. Responses on the main key will not produce reinforcement until the COD interval has expired. Each CO response reinitiates the COD interval. In both procedures, the COD prevents one schedule of reinforcement from exerting accidental control over the changeover-key pecking and the responses maintained by the other schedule.

Catania (1963,a) confirmed the relationship reported by Herrnstein

(1961), using pigeons as subjects and a COD of 2 seconds with the CO-key procedure. The two-key and the CO-key procedures thus appear to be functionally equivalent, at least with respect to matching of the relative rates of responding and reinforcement.

Schroeder and Holland (1969) have also shown the necessity of the COD for matching in a study in which human eye movement was reinforced with concurrent schedules. When COD's of 1 and 2 seconds were used, matching was obtained, but not in the absence of a COD.

There have been a number of experiments which have been performed for the purpose of investigating the effects of the COD itself. The matching relation is not affected by variations in the length of the COD, at least in the range that has thus far been investigated.

Shull and Pliskoff (1967) investigated the effects of COD duration on relative response rate. Using rats as subjects and brain stimulation as the reinforcer with the CO-key procedure, they found that the relative response rate depended on the duration of the COD when the concurrent schedules were variable-interval (VI) 1-minute and VI 3-minutes, but that the relative response rate was independent of COD duration when the VI schedules were both 1.5 minutes. However, as Allison and Lloyd (1971) pointed out, the correspondence between relative reinforcement rate and relative performance measures was essentially maintained in the Shull and Pliskoff study, since the proportion of reinforcement actually increased as the COD increased.

Silberberg and Fantino (1970) found that the proportion of pigeons' responses to one of two keys matched the proportions of

reinforcements obtained on that key when the COD was varied, although responses during the COD and after the COD deviated from matching in opposite directions. When considered together, as in other experiments, however, the responses did match the relative reinforcement rate. Relative time matched the relative reinforcement rate throughout the experiment.

Allison and Lloyd (1971) found that the proportion of pigeons' responses and time approximated the actual relative rate of reinforcement when COD intervals of 2.0, 5.0, 7.5, and 12.5 seconds were programmed. The two-key procedure was used with VI 1-min and VI 3-min schedules of reinforcement.

It is possible to program concurrent VI VI schedules so that the actual relative rate of reinforcement is fixed by the experimenter. Stubbs and Pliskoff (1969) have developed such a procedure. They found that relative response rate and relative time tended to match the relative reinforcement rate as in more standard concurrent VIVI schedules. Pear and Stevens (1971) obtained similar results using rats instead of pigeons as subjects and a slight variation in procedure.

The matching of relative time and relative reinforcement rate has received attention, both on its own and along with other measures since Catania (1966), using pigeons as subjects and the CO-key procedure, showed that the relative time spent in the presence of a given schedule and its stimulus approximated the relative rate of reinforcement provided by that schedule. Once again, the relative rate of responding was found to match the relative rate of reinforcement.

Brownstein and Pliskoff (1968) showed that in the CO-key situation the matching of relative time spent in a component to relative rate of reinforcement occurs in the absence of pecking for reinforcement. The subjects (pigeons) pecked a CO-key to change the colour of a stimulus light, but the reinforcers in each component were delivered independent of the birds' behaviour, at a rate determined by the VI schedules.

Baum and Rachlin (1969) replicated the above experiment, using a method analogous to the two-key procedure. Pigeons were reinforced for standing on one or the other side of a chamber according to two variable-interval schedules. A biased matching relation was obtained which was comparable to the matching relation obtained with concurrent reinforcement of key pecks, the difference being that the pigeons showed a constant proportional preference for the right side over the left.

Relative response rate and relative time are not limited to matching relative reinforcement rate only; the matching relation holds with other independent variables as well. One of these is relative magnitude of reinforcement. Catania (1963,b), using pigeons as subjects and the two-key procedure, found that relative rates of responding matched relative magnitudes of reinforcement, which were varied by means of changes in the duration of feeder operation. Essentially the same results were reported by Baum (1966), who used rats as subjects and varied sucrose concentration to change the relative magnitude of reinforcement.

Delay of reinforcement is another independent variable which is associated with matching. Chung (1965,b), using pigeons as subjects and the two-key procedure, found that delays of reinforcement for pecks at one key reduced the relative frequency of pecking exponentially as a

function of the delay interval. Chung and Herrnstein (1967) followed this up by investigating the effects of setting delays of various durations for both of the response alternatives. They found that the relative frequency of responding matched the relative immediacy of reinforcement in a two-response situation, immediacy defined as the reciprocal of the delay of reinforcement. Relative immediacy of reinforcement was calculated as follows:

$$(5) \quad \frac{i_e}{i_e + i_s}$$

where i is the reciprocal of the delays on the experimental (e) and standard (s) keys.

Shimp (1969) replicated the Chung and Herrnstein (1967) study with one change; when a reinforcer was assigned for a peck on a key, one response on that key initiated a blackout and the next response on that key (after the blackout) was immediately reinforced. Once again, it was found that relative frequency of responding on a key matched the relative immediacy of reinforcement on that key.

Herbert (1970) found that matching was obtained when each response initiated a blackout and reinforcement following blackouts was response-independent (Experiment I). In Experiment II, a rough approximation to matching was obtained when each response initiated a blackout and reinforcement following blackouts was response-independent. Matching was not obtained in Experiment III, when response-reinforcement dependencies were different between keys.

Still another independent variable associated with matching is the force requirement of the operanda. Chung (1965,a), using pigeons

as subjects, varied the key-peck force required for reinforcement in a single-key situation. Using the data thus obtained, he was able to predict the distribution of responses in a two-key concurrent VI VI situation by means of the formula:

$$(6) \quad \frac{R_{f1}}{R_{f1} + R_{f2}}$$

where R_{f1} and R_{f2} are the total responses emitted at the two given forces in the first experiment. When he varied the VI schedules, he found that the decrement in response rate due to the increased force requirement was proportionally higher for the key with the lower rate of scheduled reinforcement.

The investigation of matching relationships has not been confined to concurrent VI VI studies. There also exists a body of research concerned with behaviour maintained by concurrent-chain schedules of reinforcement, or concurrent schedules of conditioned reinforcement. In the concurrent-chain procedure, responses to either of two keys occasionally produce a stimulus correlated with a schedule of primary reinforcement. When this schedule is in effect on one key, the other key is dark and inoperative.

Several experiments designed to investigate the matching relation have been performed using the concurrent-chain procedure; since they are not vital to the understanding of the present experiment, they will not be reviewed here. The concerned reader may consult the following: Autor (1960), Reynolds (1963), Herrnstein (1964a,b), Fantino (1967), Fantino (1968), Fantino and Herrnstein (1968), Killeen (1968), Davison (1969), Fantino (1969), Schwartz (1969), Duncan and Fantino (1970),

Killeen (1970), Ten Eyck (1970), and Squires and Fantino (1971).

As can be seen by this literature review, much of the research that has been performed to investigate concurrent operants has dealt with the manner in which organisms distribute their responses between the concurrent schedules of reinforcement. Several investigators (e.g., Catania, 1966; Shull and Pliskoff, 1967; Brownstein and Pliskoff, 1968; Stubbs and Pliskoff, 1969) have found that relative response rate and relative time on each operant approximate, or match, the relative reinforcement rate for that operant. In all such studies, the concurrent schedules of reinforcement have been correlated with either different manipulanda or different stimuli. However, it is not known what sort of relation would exist between (1) relative response rate and relative reinforcement rate, and (2) relative time and relative reinforcement rate if this were not the case. That is, if neither different manipulanda nor different stimuli were correlated with the concurrent schedules, what would the effect be on the matching relation? The purpose of this experiment was to answer the above question.

Since a concurrent schedule is much like a multiple schedule in that each component has a distinct stimulus associated with it, it was necessary to develop a schedule which, although retaining some of the characteristics of the standard concurrent schedule, would be similar to a mixed schedule, in which different stimuli are not associated with the components. The schedule used in the present experiment was termed a "mixed-concurrent schedule" by the author, since it resembled both a mixed and a concurrent schedule. By exposing the subjects to both the

standard concurrent schedule of reinforcement as well as the mixed-concurrent schedule of reinforcement, it would be possible to evaluate the effect of the different stimuli associated with the components of the concurrent schedule.

CHAPTER III

STATEMENT OF THE PROBLEM

The preceding literature survey indicates that matching of relative performance measures and relative frequency of reinforcement is obtained under several different conditions. There is, however, an element which is common to all the above experiments - the correlation of a separate stimulus or separate operandum with each concurrent schedule of reinforcement. The experiment in this thesis sought to determine whether or not this condition was necessary for matching to be obtained. That is, would anything like a matching relation be obtained when separate stimuli were not used? It was hoped that the study would extend the present knowledge of the matching phenomenon.

CHAPTER IV

METHOD

Subjects

Four Holtzman male albino rats (M-3, T-1, T-3, T-4) served as subjects. M-3 and T-1 were 118 days of age at the beginning of the experiment; T-3 and T-4 were 60 days of age. All subjects were experimentally naive. The subjects were given free access to food and water until a food deprivation schedule was initiated and continued until the subjects reached 80% normal body weight, defined as the mean body weight over the last five days of ad lib food and water. The subjects were maintained at 80% normal body weight for the remainder of the investigation by food reinforcement received during the experimental session and by supplements of Purina rat food.

Apparatus

The experimental space consisted of a dual lever Lehigh Valley Electronics operant conditioning chamber, Model 1316, mounted in a Model 1316C cubicle. The inside dimensions of the chamber were 7.5 in high by 12 in long by 8 in wide (19 cm X 30.6 cm X 20.3 cm). The two levers were mounted 1 3/16 in (2.8 cm) above the grid floor. Both levers were on the same 8-in wide wall and each was 7/8 in (2.2 cm) from one of the two adjoining 12-in walls. A force of approximately 24 grams was required to operate each lever. A 7-watt house light was used as a stimulus. Food reinforcement, consisting of .01 ml. of a 1:1 mixture of Borden's sweetened condensed milk and tap water, was delivered by a dipper used in the normally up position. Dipper operation

by a solenoid produced an immediate audible conditioned reinforcer; food reinforcement was delayed by approximately 0.5 sec., the time required for the delivery cycle. An exhaust fan in the cubicle provided a masking noise. Standard state programming and recording equipment and a Gerbrands cumulative recorder were located in a nearby room.

Procedure

Before the experiment began, subjects were pretrained for three days. During the pretraining period the lever-pressing response was established and the animals were exposed to CRF on both levers. They were then transferred directly to the concurrent VI VI schedules.

During the first ascending and descending sequences, when concurrent VI VI schedules were in effect, responses on the right-hand lever (main lever) were reinforced on a variable-interval (VI) 60-sec schedule when the house light was on. When the house light was off, the contingency in effect was one of a range discussed shortly. Each response on the left-hand lever (changeover lever) alternated the stimulus from light on to light off or vice-versa. After each changeover response there was a changeover delay (COD) during which reinforcement was unavailable. If a reinforcer had been set up during this delay, it remained set up until delivered. The COD was of two seconds duration for Subjects M-3 and T-1, and of four seconds duration for Subjects T-3 and T-4. These durations remained constant throughout the entire experiment. The longer COD was used for two subjects to provide information as to whether or not two seconds was too short an interval.

The contingency in effect when the house light was off was

varied through the sequences described below:

First ascending and descending sequences. A two-channel tape programmer (BRS Foringer), with a drive mechanism that operated every second, was used to assign reinforcements. When a photo-sensor mechanism detected a punched hole in the tape in one channel, a reinforcer was assigned to the light-on condition (condition 1); when it detected a hole in the other channel, a reinforcer was assigned to the light-off condition (condition 2). The tape halted when a hole was detected in either channel and restarted when a response occurred in the presence of the required stimulus condition. The proportion of reinforcements in each of the stimulus conditions thus depended on the proportion of holes in each channel of the VI tape. This procedure is similar to that used by Stubbs and Pliskoff (1969). The number of holes in the channel associated with condition 1, relative to the total number of holes, was varied through a series which first ascended and then descended. Sessions lasted for one hour. The concurrent schedules in effect were varied as shown in Tables 1 and 2.

Each subject was maintained on a given concurrent schedule for a minimum of 5 sessions and until its response pattern was stable for 4 consecutive sessions. The stability criterion stipulated that the proportion of responses made in Condition 1 to the total number of responses, during each of the last 4 consecutive sessions had to be within 3% of the mean proportion for all 4 sessions; and, that the proportion of time spent in Condition 1 to the total session time, during each of the last 4 sessions had to be within 3% of the mean proportion for all 4 sessions. This was the same stability criterion utilized by Pear

Table 1. Summary of experimental procedure during first ascending and descending sequences with a separate stimulus correlated with each concurrent schedule for Subjects M-3 and T-4. The VI values are in seconds.

Schedule		Relative Reinforcement Rate (Condition 1)	Number of Sessions
Condition 1	Condition 2		
Light ON	Light OFF		
Subject M-3			
First ascending sequence			
VI 60	VI 20	.25	9
VI 60	VI 60	.50	6
VI 60	VI 180	.75	11
VI 60	Ext	1.00	7
First descending sequence			
VI 60	VI 180	.75	16
VI 60	VI 60	.50	5
VI 60	VI 20	.25	10
Subject T-4			
First ascending sequence			
VI 60	VI 20	.25	25
VI 60	VI 60	.50	10
VI 60	VI 180	.75	5
VI 60	Ext	1.00	15
First descending sequence			
VI 60	VI 180	.75	8
VI 60	VI 60	.50	23
VI 60	VI 20	.25	5

Table 2. Summary of experimental procedure during first ascending and descending sequences with a separate stimulus correlated with each concurrent schedule for Subjects T-1 and T-3. The VI values are in seconds.

Schedule		Relative Reinforcement Rate (Condition 1)	Number of Sessions
Condition 1	Condition 2		
Light ON	Light OFF		
Subject T-1			
First ascending sequence			
VI 60	VI 20	.25	15
VI 60	VI 60	.50	9
VI 60	VI 180	.75	5
VI 60	Ext	1.00	5
First descending sequence			
VI 60	VI 180	.75	14*
VI 60	VI 60	.50	48*
VI 60	VI 20	.25	48
Subject T-3			
First ascending sequence			
VI 60	VI 20	.25	22
VI 60	VI 60	.50	8
VI 60	VI 180	.75	21
VI 60	Ext	1.00	7
First descending sequence			
VI 60	VI 180	.75	6
VI 60	VI 60	.50	8
VI 60	VI 20	.25	7

* Unstable after 48 sessions

and Stevens (1971). The number of sessions required to meet this criterion for each concurrent schedule is shown in Tables 1 and 2. If the stability criterion was not met within 48 sessions, the subject was switched to the next concurrent schedule.

Second ascending and descending sequences. The procedure for these sequences was essentially identical to that described above, except that responses on the changeover lever did not alternate the stimulus. Responses on the changeover lever did, however, alternate the reinforcement schedule as in the first ascending and descending sequences. The tape drive was halted whenever a hole was detected in either channel and did not restart until a response occurred in the appropriate condition. Conditions 1 and 2 were no longer correlated with light on and light off. The house light remained on throughout all sessions for Subjects M-3 and T-4 and off throughout all sessions for Subject T-3. The mixed concurrent schedules in effect were varied as in the first ascending and descending sequences except for Subject M-3 who was exposed to two additional mixed concurrent schedules after the regular sequence. The number of sessions required to meet the stability criterion for each mixed concurrent schedule are shown in Tables 3 and 4. Data for Subject T-1 are not shown as he succumbed to illness early in the second ascending sequence.

Table 3. Summary of experimental procedure during second ascending and descending sequences with no separate stimulus correlated with each concurrent schedule for Subjects M-3 and T-4. The VI values are in seconds.

Schedule		Relative Reinforcement Rate (Condition 1)	Number of Sessions
Condition 1	Condition 2		
Light ON	Light ON		
Subject M-3			
Second ascending sequence			
VI 60	VI 20	.25	8
VI 60	VI 60	.50	11
VI 60	VI 180	.75	6
VI 60	Ext	1.00	28
Second descending sequence			
VI 60	VI 180	.75	8
VI 60	VI 60	.50	5
VI 60	VI 20	.25	6
VI 60	VI 6.67	.10	11
VI 60	VI 3.16	.05	6
Subject T-4			
Second ascending sequence			
VI 60	VI 20	.25	9
VI 60	VI 60	.50	9
VI 60	VI 180	.75	9*
VI 60	Ext	1.00	48*
Second descending sequence			
VI 60	VI 180	.75	10
VI 60	VI 60	.50	11
VI 60	VI 20	.25	5

* Unstable after 48 sessions

Table 4. Summary of experimental procedure during second ascending and descending sequences with no separate stimulus correlated with each concurrent schedule for Subject T-3. The VI values are in seconds.

Schedule		Relative Reinforcement Rate (Condition 1)	Number of Sessions
Condition 1	Condition 2		
Light OFF	Light OFF		
Subject T-3			
Second ascending sequence			
VI 60	VI 20	.25	8
VI 60	VI 60	.50	10
VI 60	VI 180	.75	12*
VI 60	Ext	1.00	48
Second descending sequence			
VI 60	VI 180	.75	11
VI 60	VI 60	.50	42
VI 60	VI 20	.25	13

* Unstable after 48 sessions

CHAPTER V

RESULTS AND DISCUSSION

The relative overall response rates approximate the relative rates of reinforcement in the first ascending and descending sequences, but the slope is less than 1.0 in all cases, as indicated by Figures 1 through 4. The arrows (\uparrow) show where points coincide for both the ascending and descending sequences. The best fit lines, calculated by means of the method of least squares, are also indicated. These data are similar to the data obtained by Pear and Stevens (1971). The relative overall response rates do not approximate the relative reinforcement rate in the second ascending and descending sequences, but are equal to approximately .50 in most cases, as shown in Figures 5, 6, and 7. Perfect matching is represented by the diagonal line with a slope of 1.0 in the above figures. In Figure 5 the best fit line does not take into account the two extra points where the relative reinforcement rate is equal to .05 and .10 since the points are not equally spaced as is the case with all of the other points. At these two points the relative response rate tends toward matching. This is not the case at the upper end of the range of values, however. At the lower end, it seemed as though the subject was able to discriminate between Condition 1 and Condition 2 in such a manner as to come close to matching. At the upper end of the range, however, the subject distributed his responses almost evenly between the two conditions even though all reinforcements were delivered in one condition. The reason for the apparent contradiction possibly lies in the different frequencies of reinforcement.

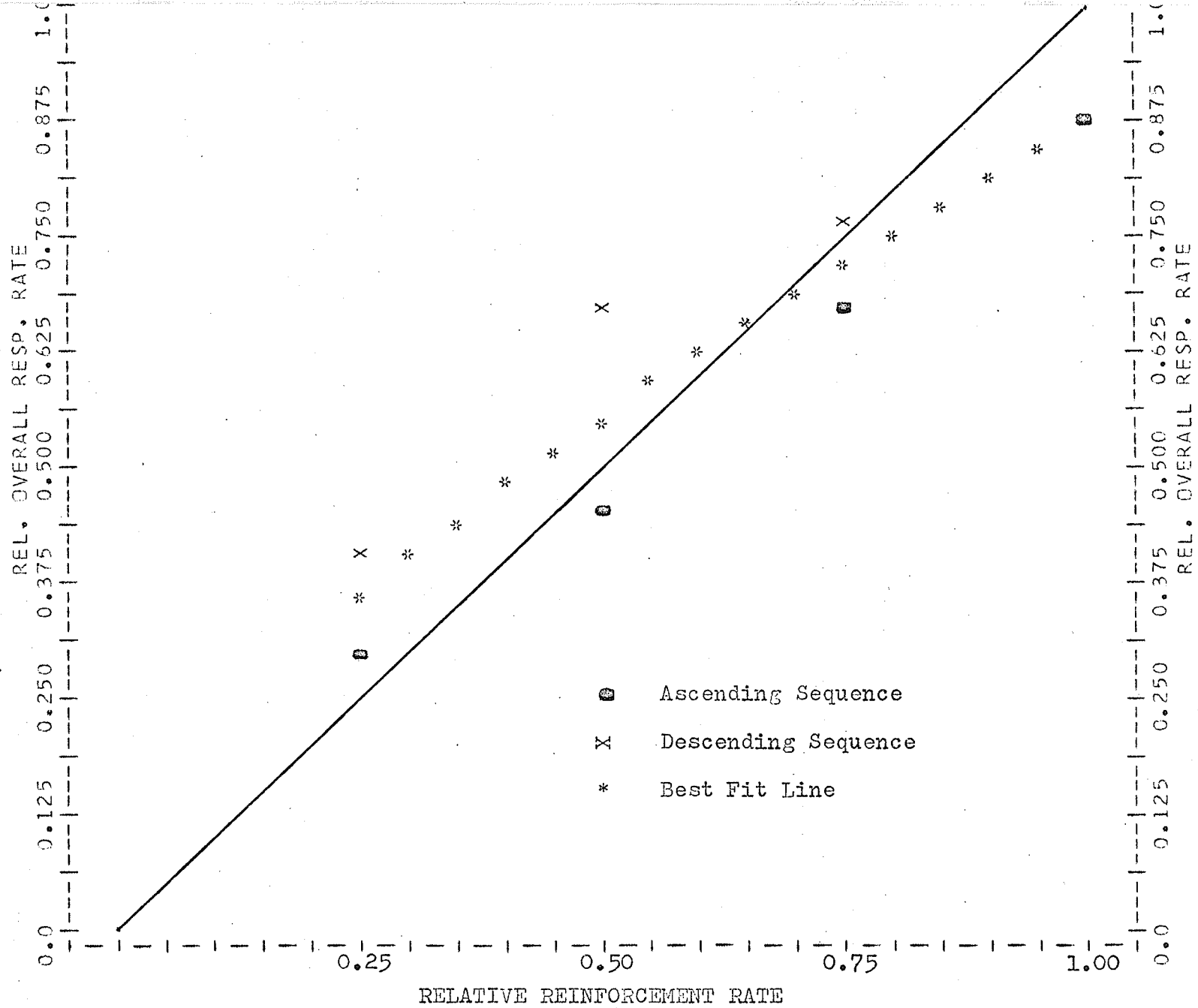


Fig. 1 Relative overall response rate as a function of relative reinforcement rate for Subject M-3. The first ascending and descending sequences are shown.

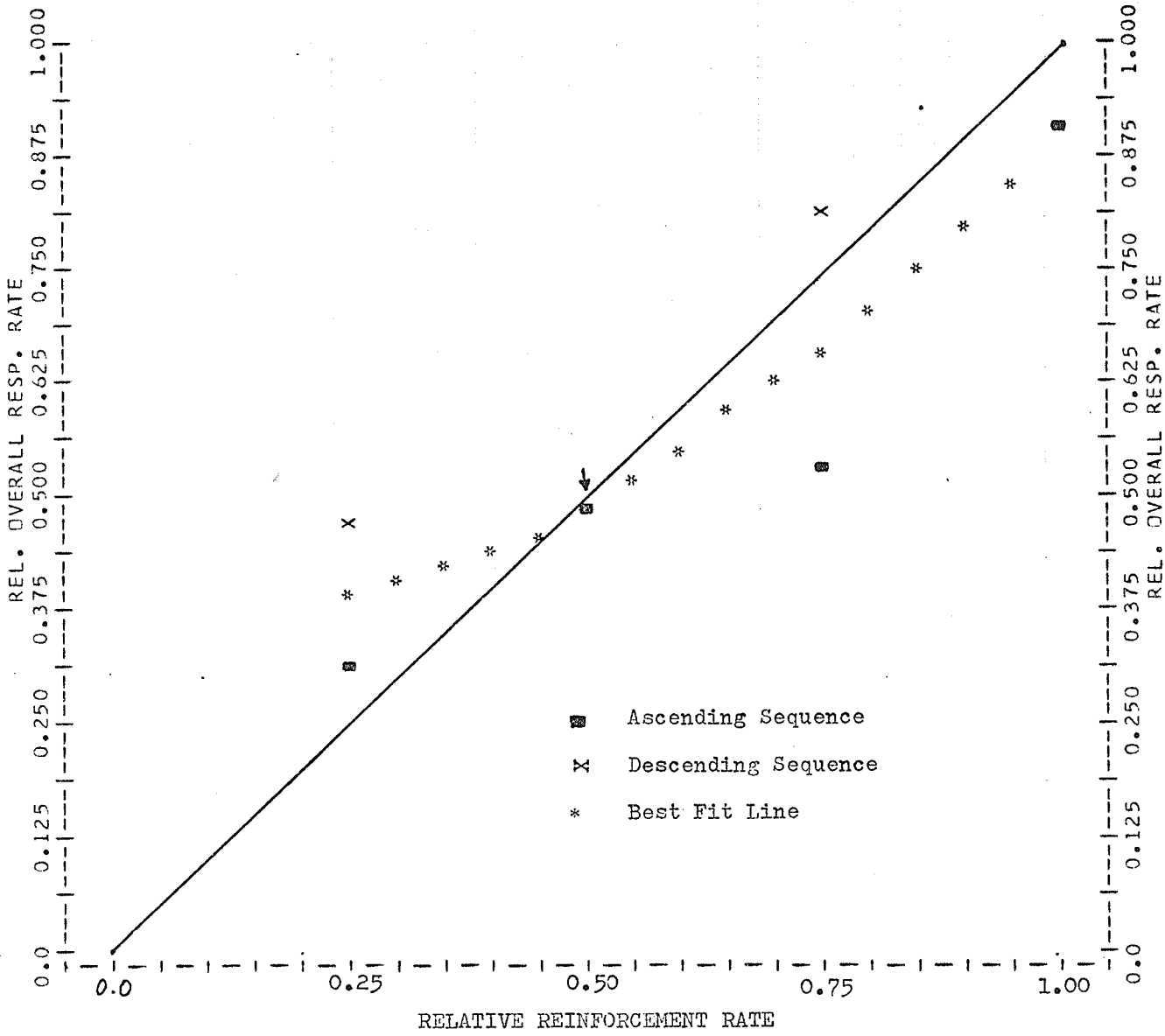


Fig. 2 Relative overall response rate as a function of relative reinforcement rate for Subject T-4. First ascending and descending sequences are shown.

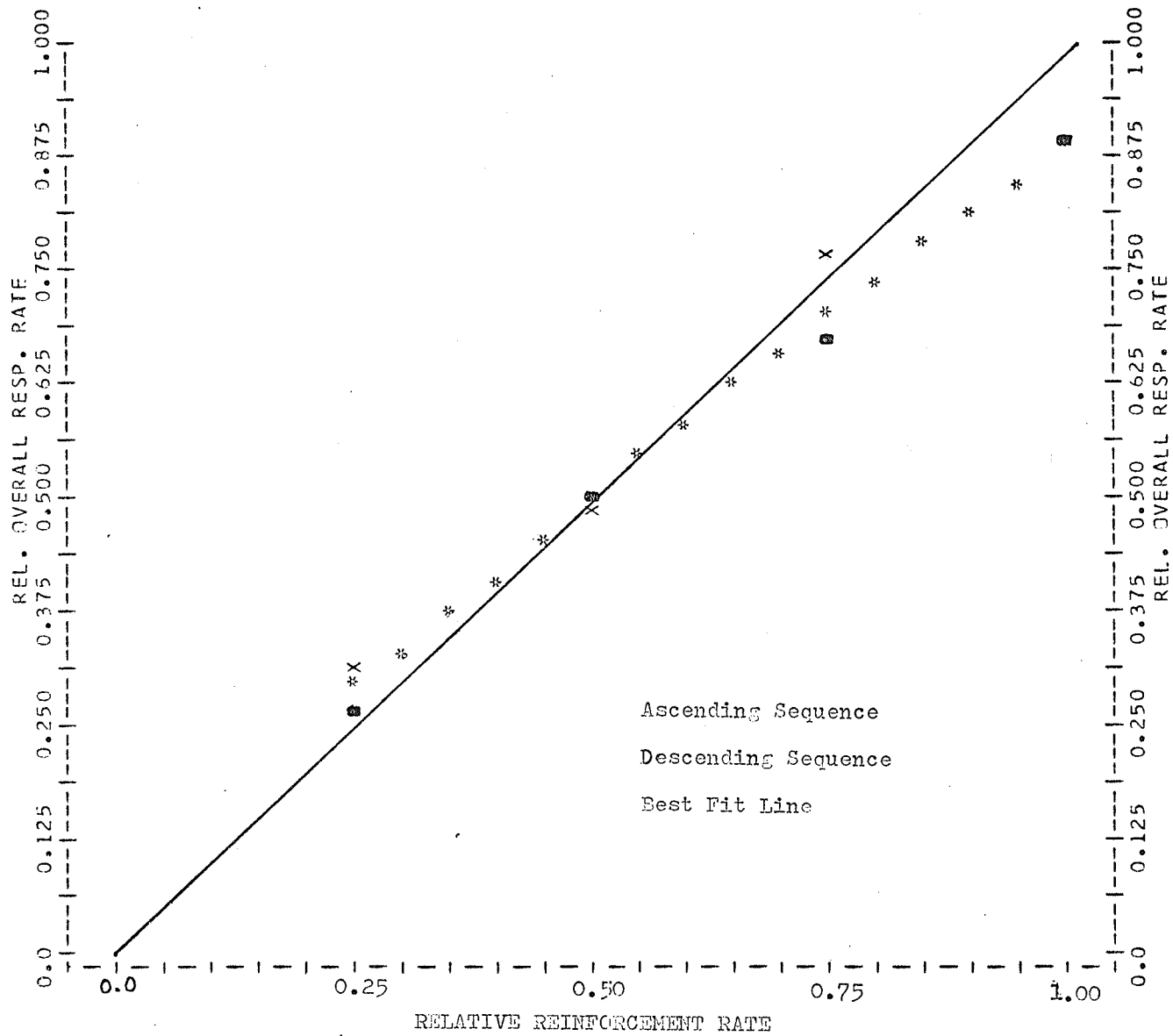


Fig. 3 Relative overall response rate as a function of relative reinforcement rate for Subject T-1. The first ascending and descending sequences are shown.

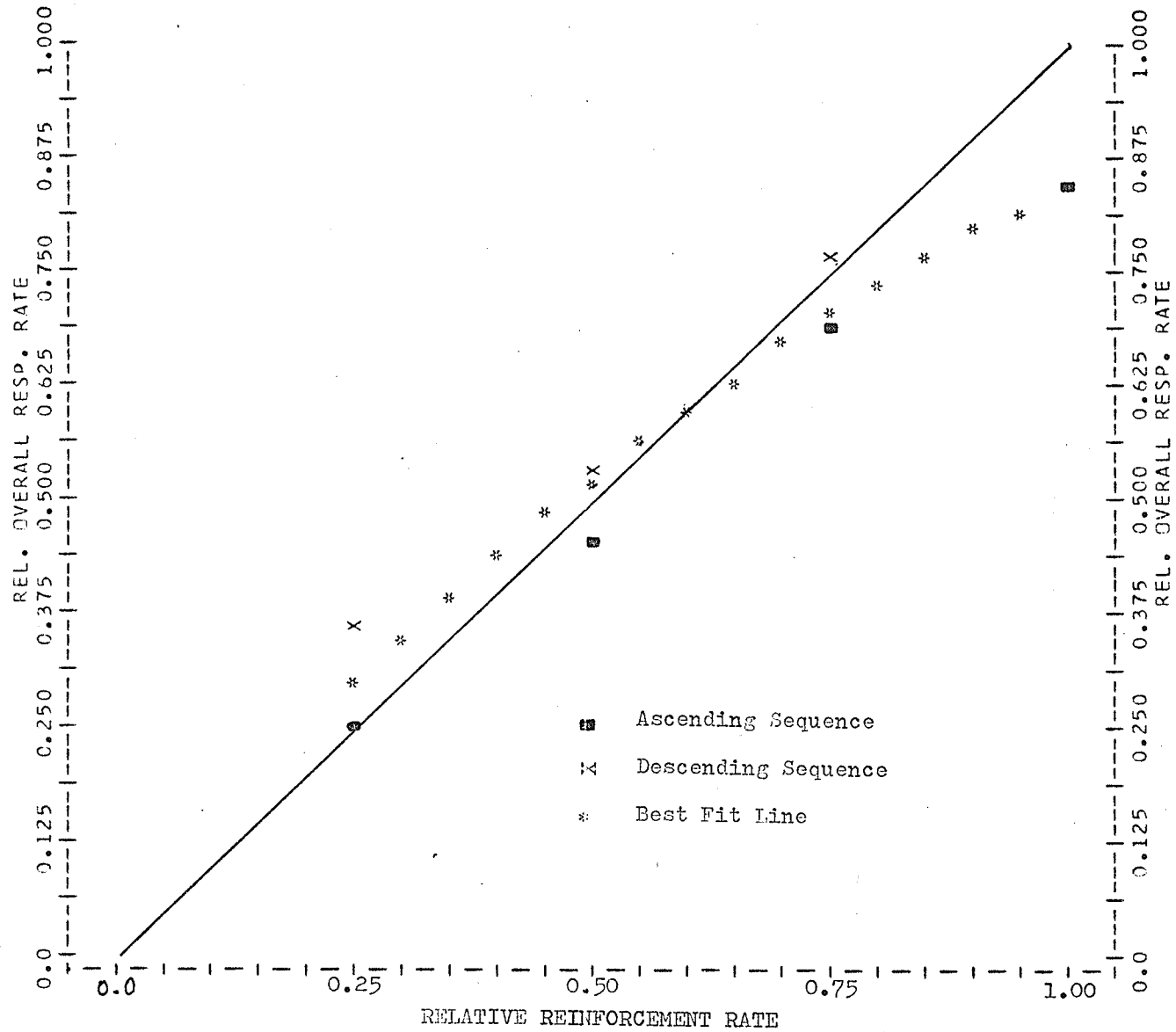


Fig. 4 Relative overall response rate as a function of relative reinforcement rate for Subject T-3. The first ascending and descending sequences are shown.

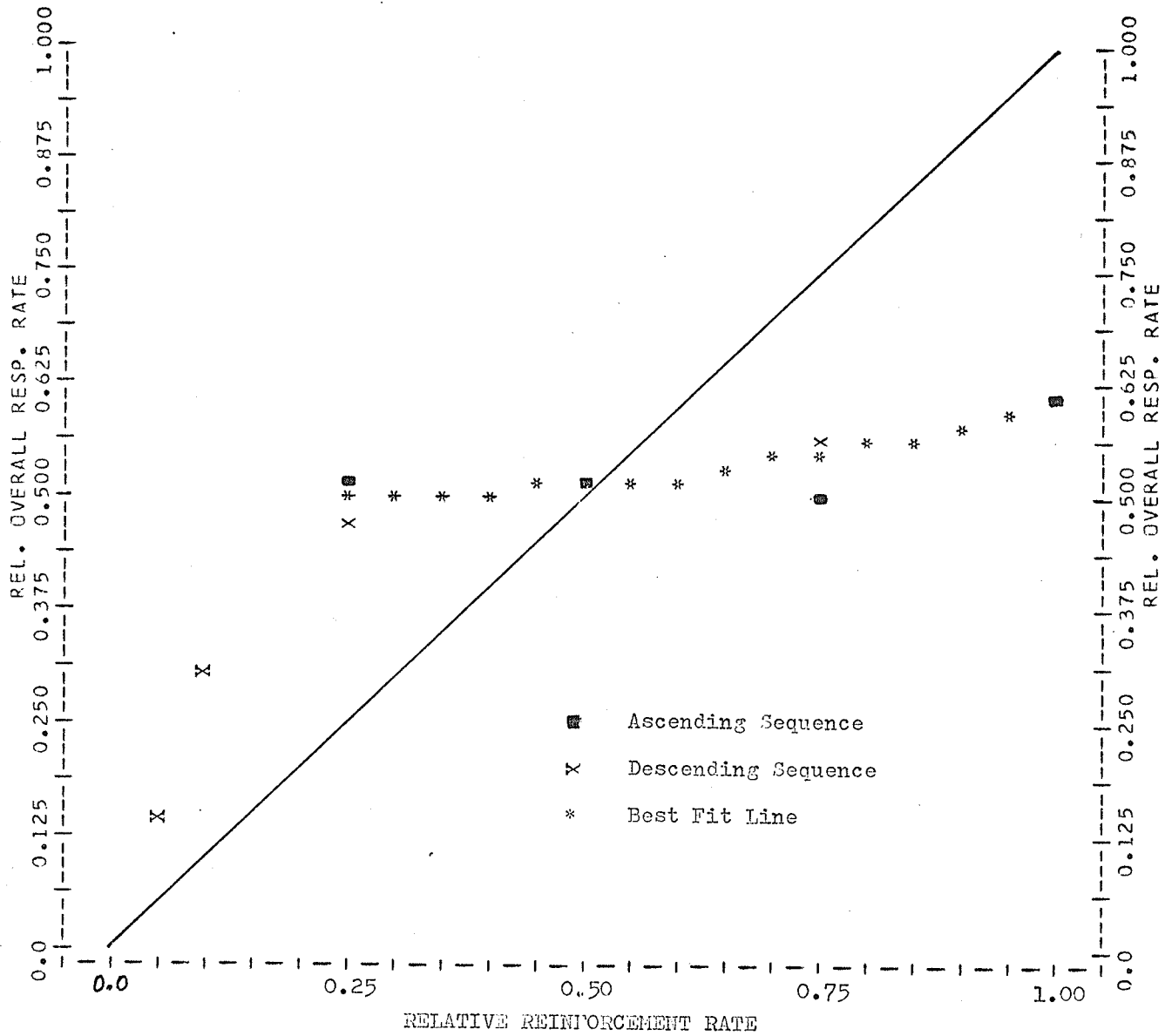


Fig. 5 Relative overall response rate as a function of relative reinforcement rate for Subject M-3. The second ascending and descending sequences are shown.

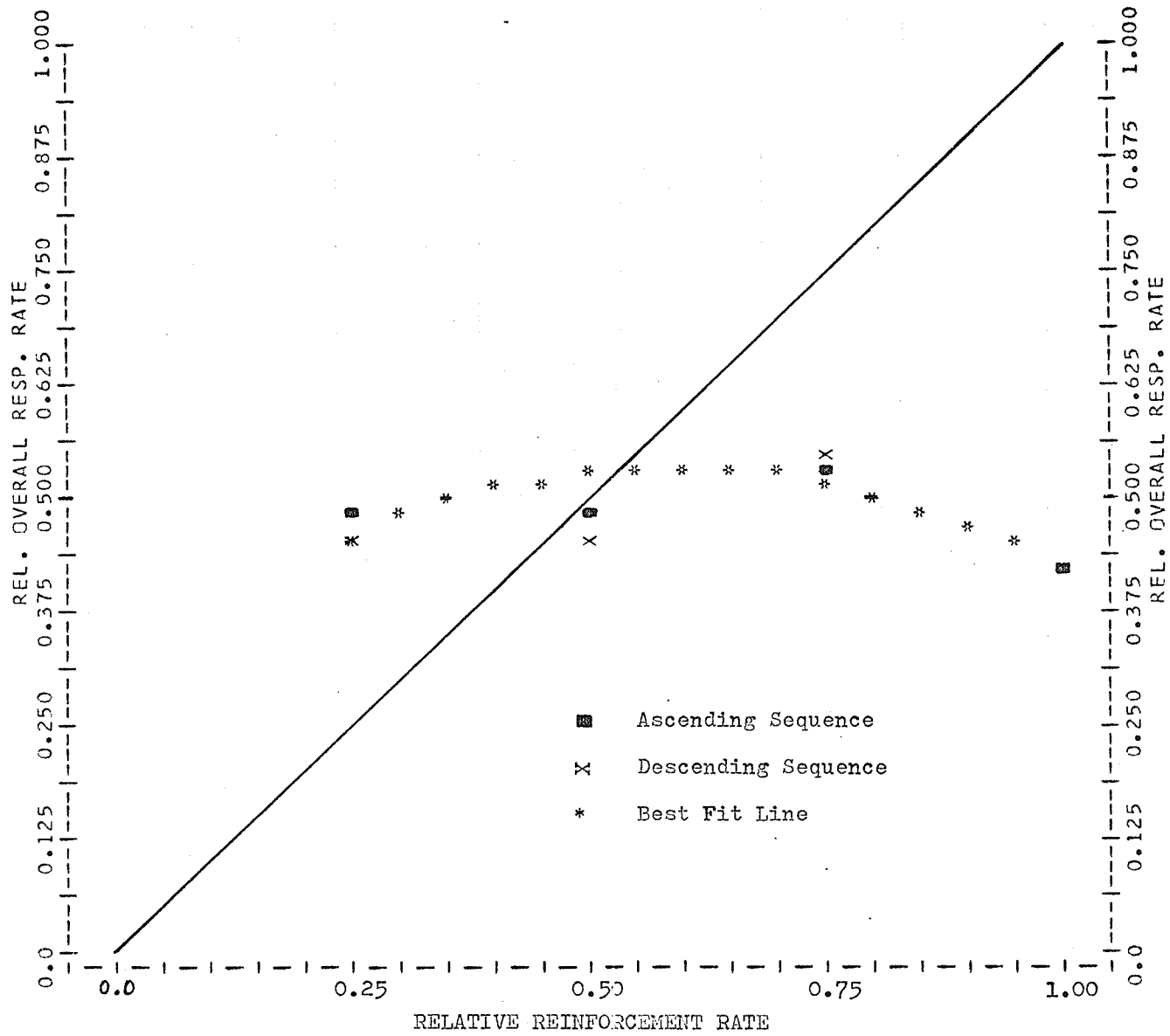


Fig. 6 Relative overall response rate as a function of relative reinforcement rate for Subject T-4. Second ascending and descending sequences are shown.

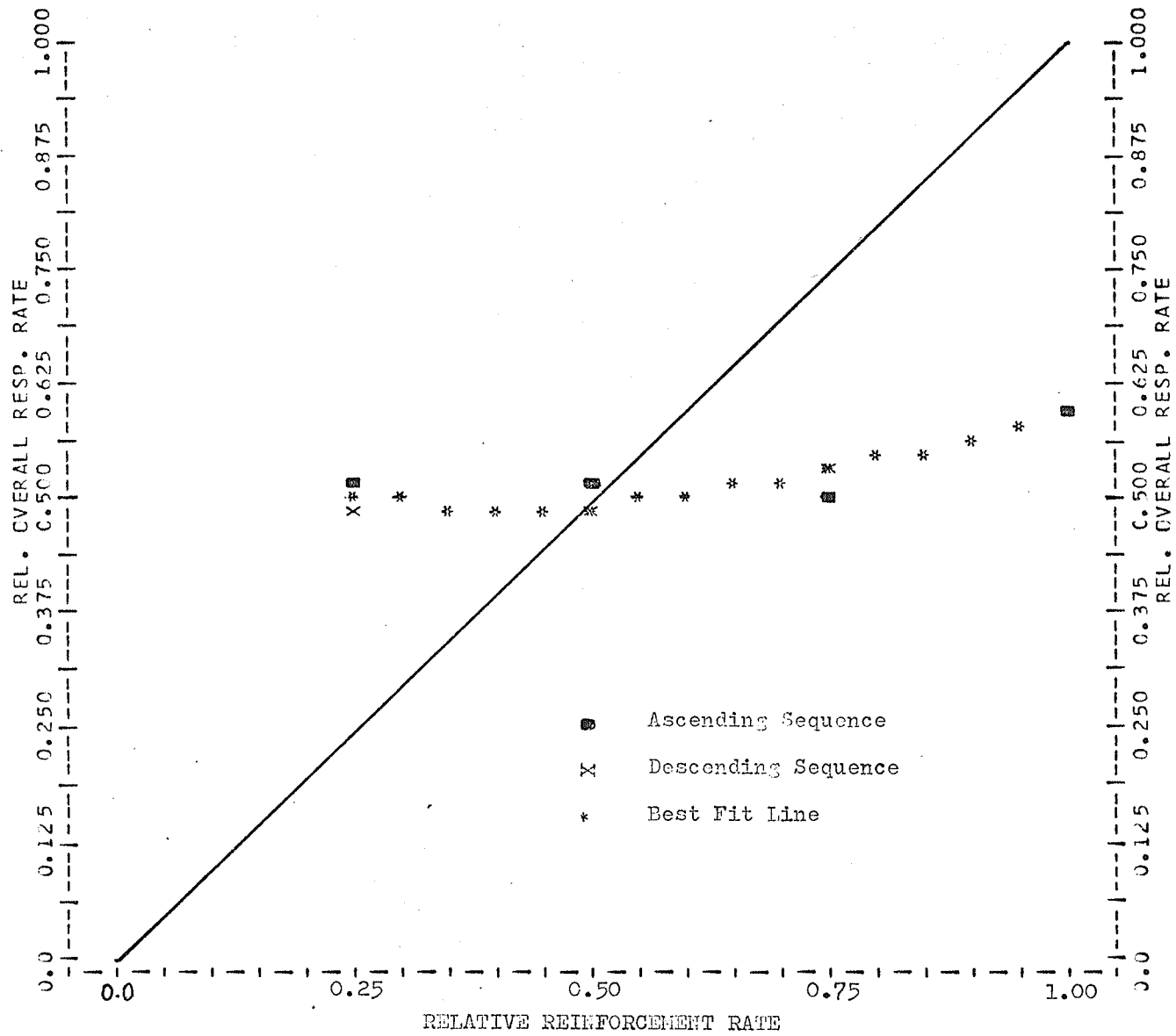


Fig. 7 Relative overall response rate as a function of relative reinforcement rate for Subject T-3. The second ascending and descending sequences are shown.

In one case, when the relative reinforcement rate was equal to 1.0, the subject was exposed to VI 60 seconds in one condition and Extinction in the other. In the other case, the subject was exposed to VI 60 in one condition and VI 3.16 in the other. The relative reinforcement rate was .05. The subject probably came to discriminate between the two conditions in the latter case on the basis of frequency of reinforcement while in the VI 60-Extinction situation, there was not enough difference between the two conditions for the subject to discriminate.

The relative times approximated the relative rates of reinforcement in the first ascending and descending sequences, as shown in Figures 8 through 11. Once again, the arrows (\uparrow) show where points coincide for both the ascending and descending sequences. The slope is less than one again in all cases. Figures 12, 13, and 14 show that the relative times more closely approximate .50 in the second ascending and descending sequences. Perfect matching is represented by the diagonal line with a slope of 1.0 in the above figures. Once again, in Figure 9 the best fit line does not take into account the two lowest points. These are similar to the corresponding points in Figure 2 in that they tend toward matching. It is possibly for the reason postulated above: the subject can discriminate between the two conditions on the basis of reinforcement frequency while it is not as readily possible when the reinforcements are more sparse. When the relative reinforcement rate is equal to 1.0 the relative time does tend slightly toward matching, but not to the extent that the lowest points do.

The relative local response rate approximated .50, which is

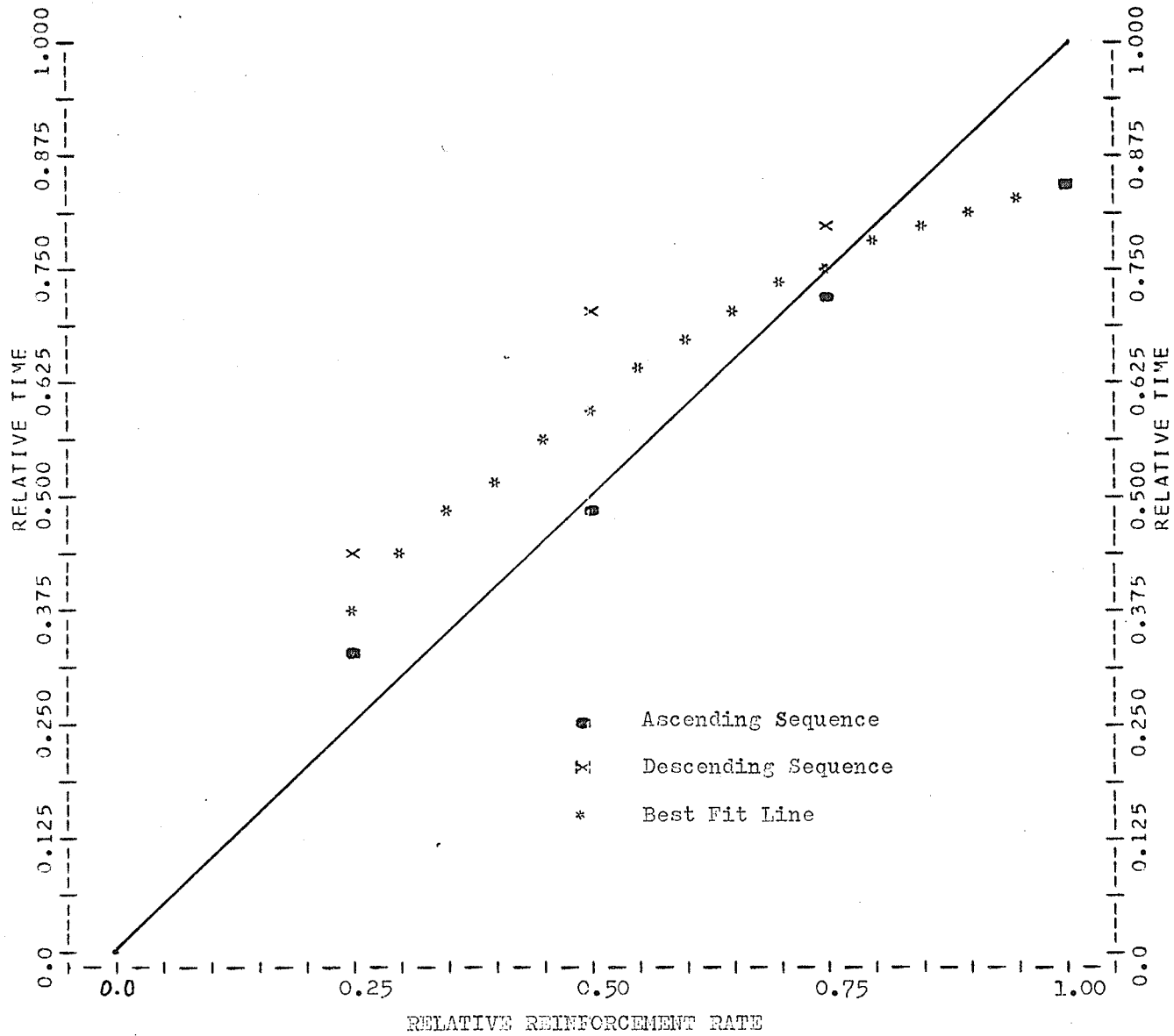


Fig. 8 Relative time as a function of relative reinforcement rate for Subject M-3. The first ascending and descending sequences are shown.

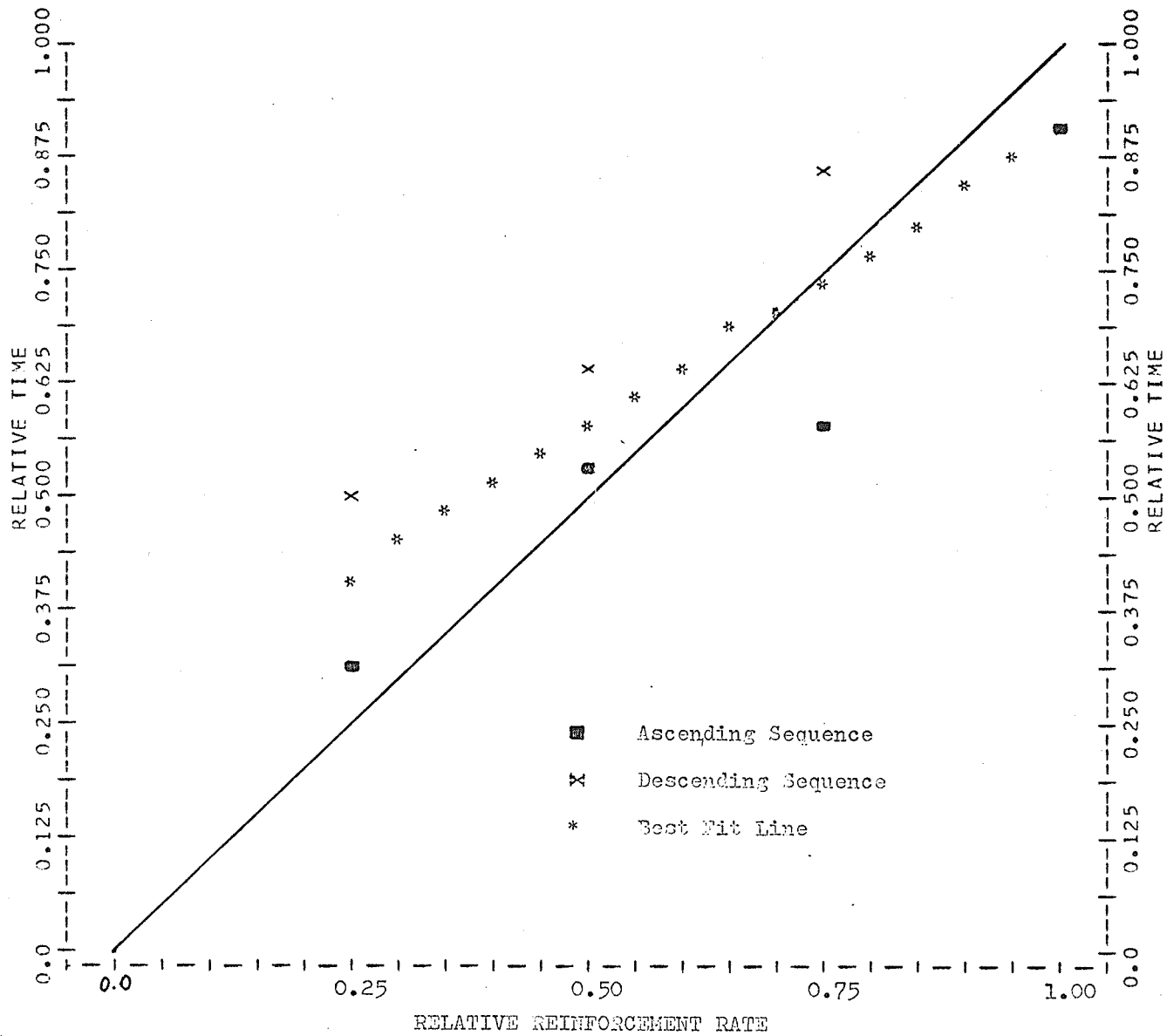


Fig. 9 Relative time as a function of relative reinforcement rate for Subject T-4. The first ascending and descending sequences are shown.

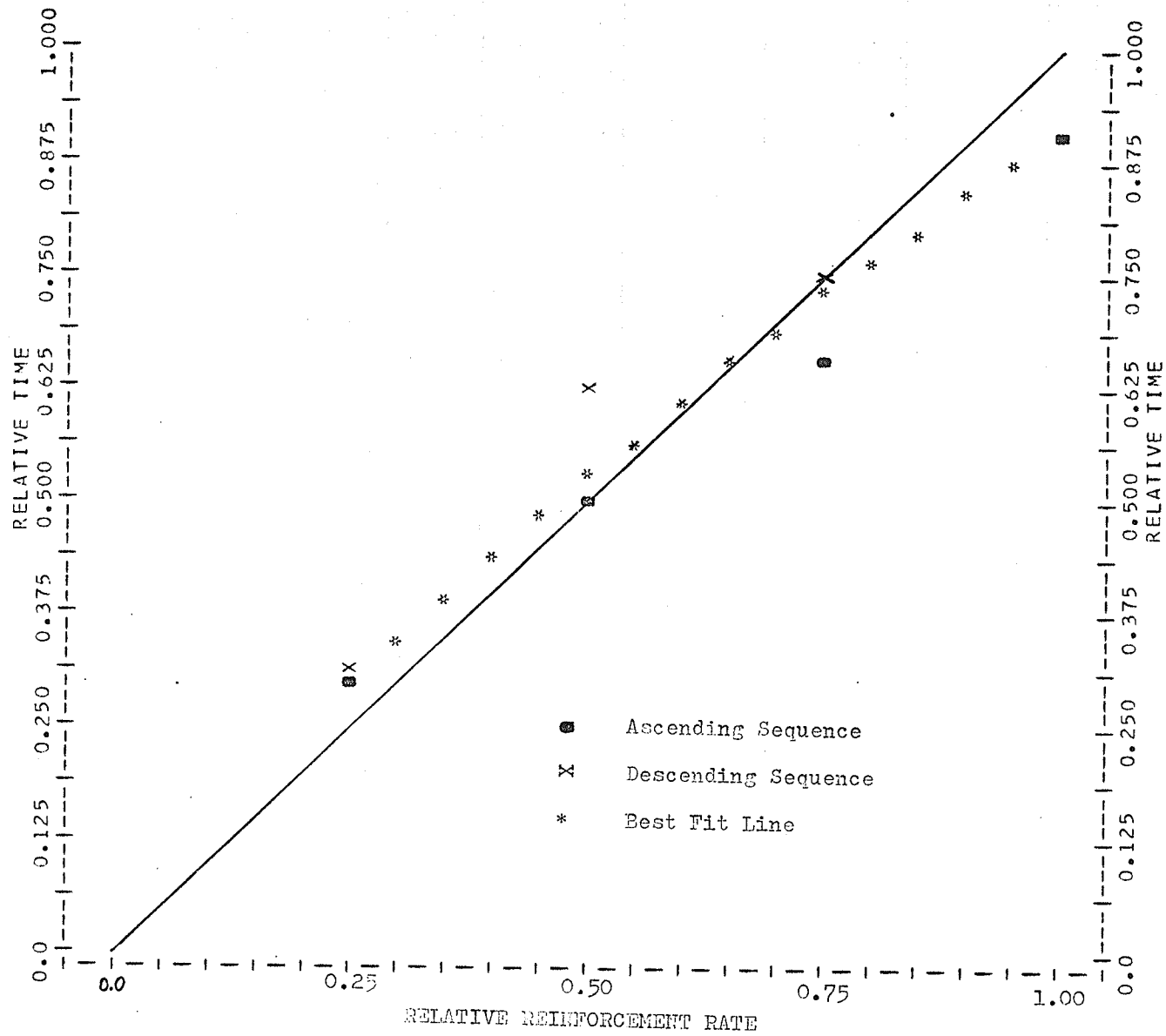


Fig. 10 Relative time as a function of relative reinforcement rate for Subject T-1. The first ascending and descending sequences are shown.

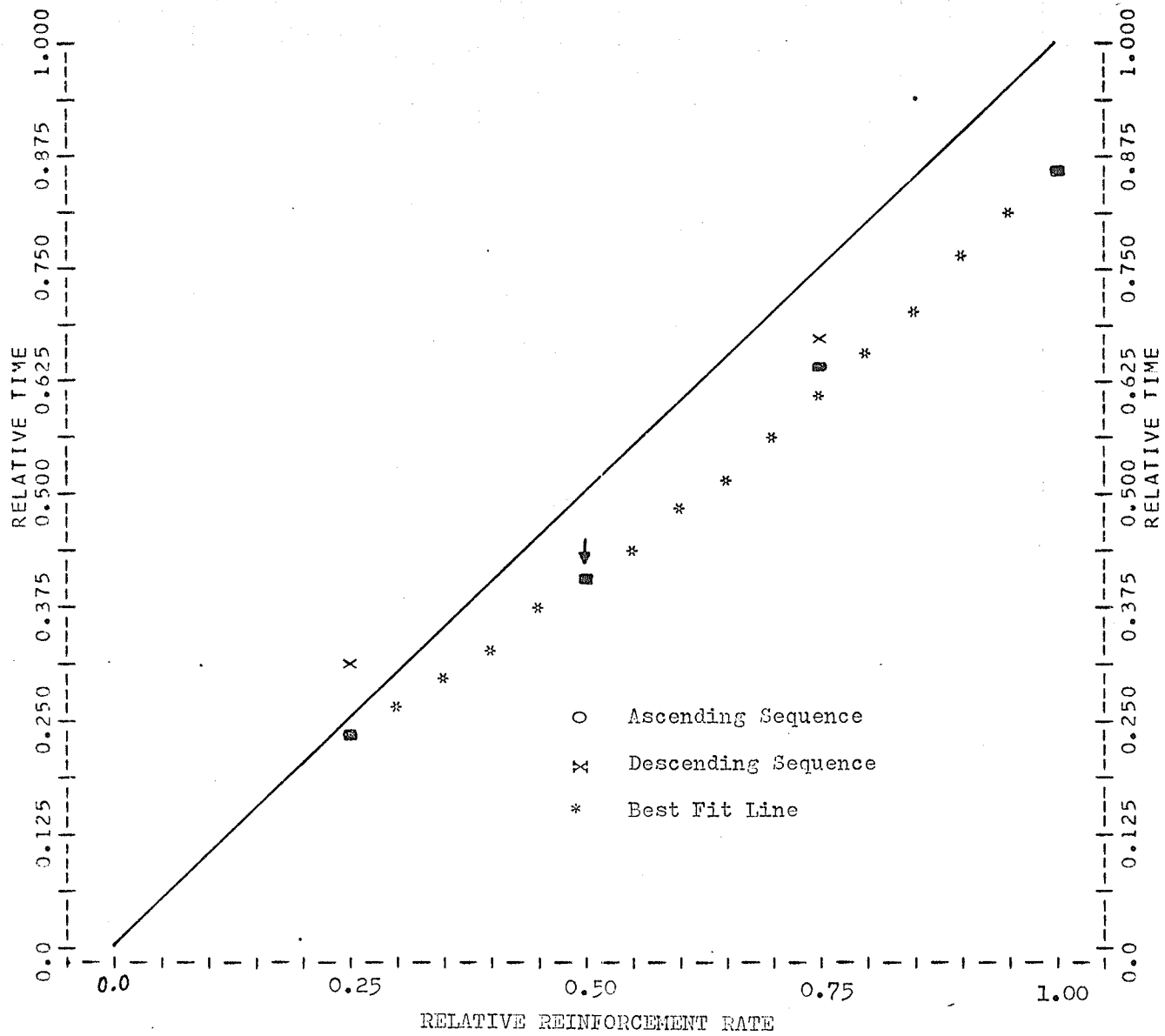


Fig. 11 Relative time as a function of relative reinforcement rate for Subject T-3. The first ascending and descending sequences are shown.

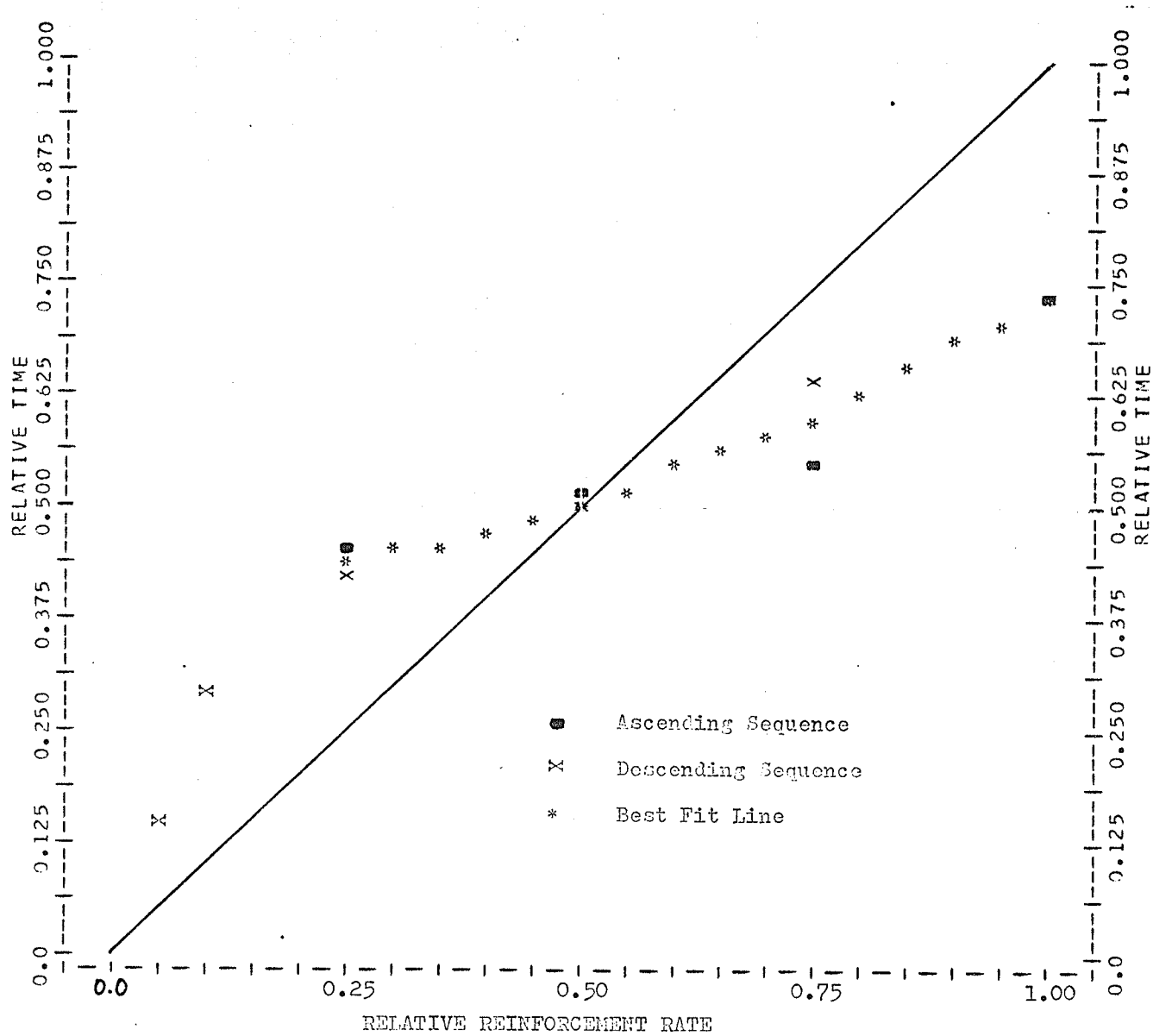


Fig. 12 Relative time as a function of relative reinforcement rate for Subject M-3. The second ascending and descending sequences are shown.

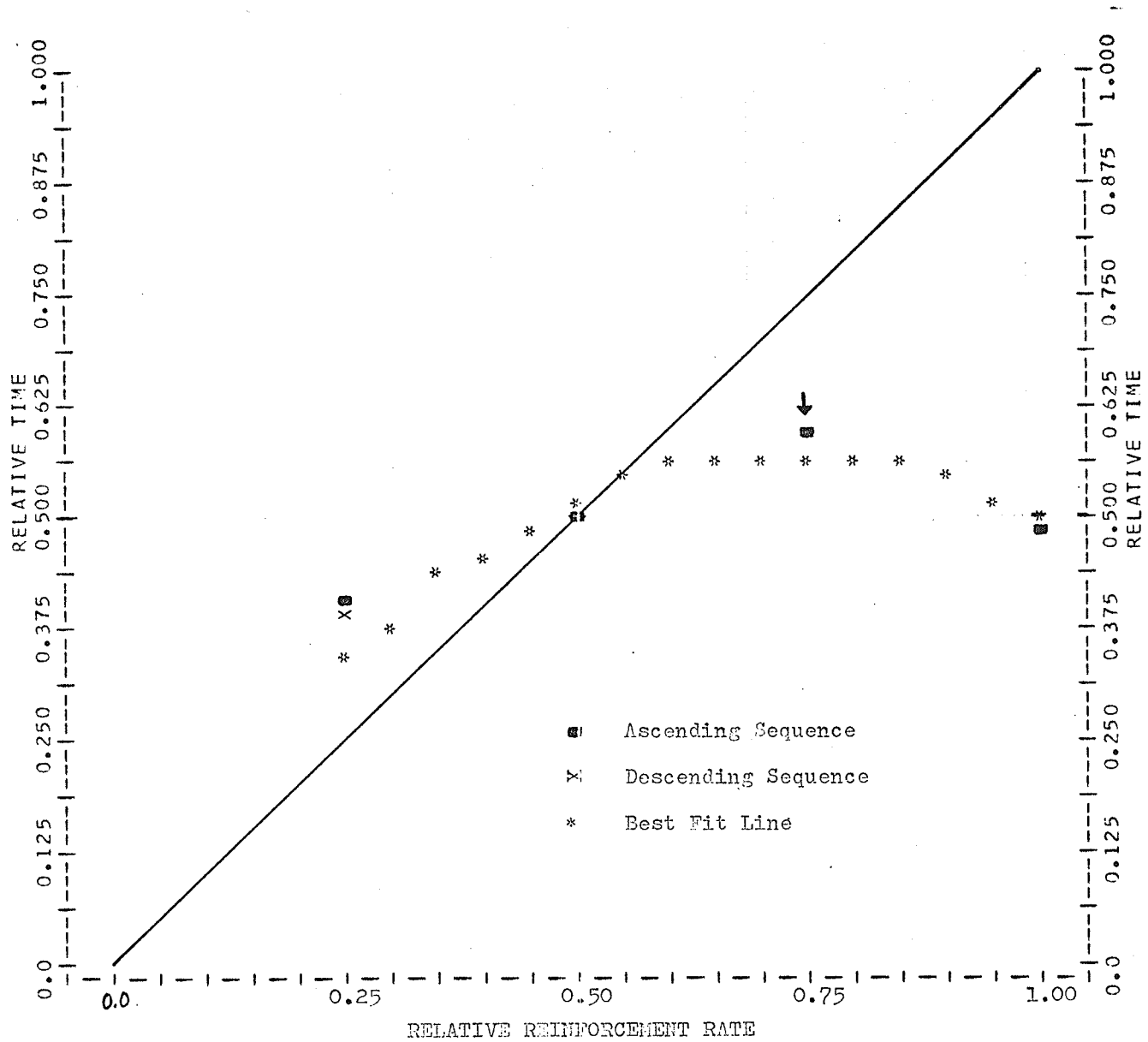


Fig. 13 Relative time as a function of relative reinforcement rate for Subject T-4. The second ascending and descending sequences are shown.

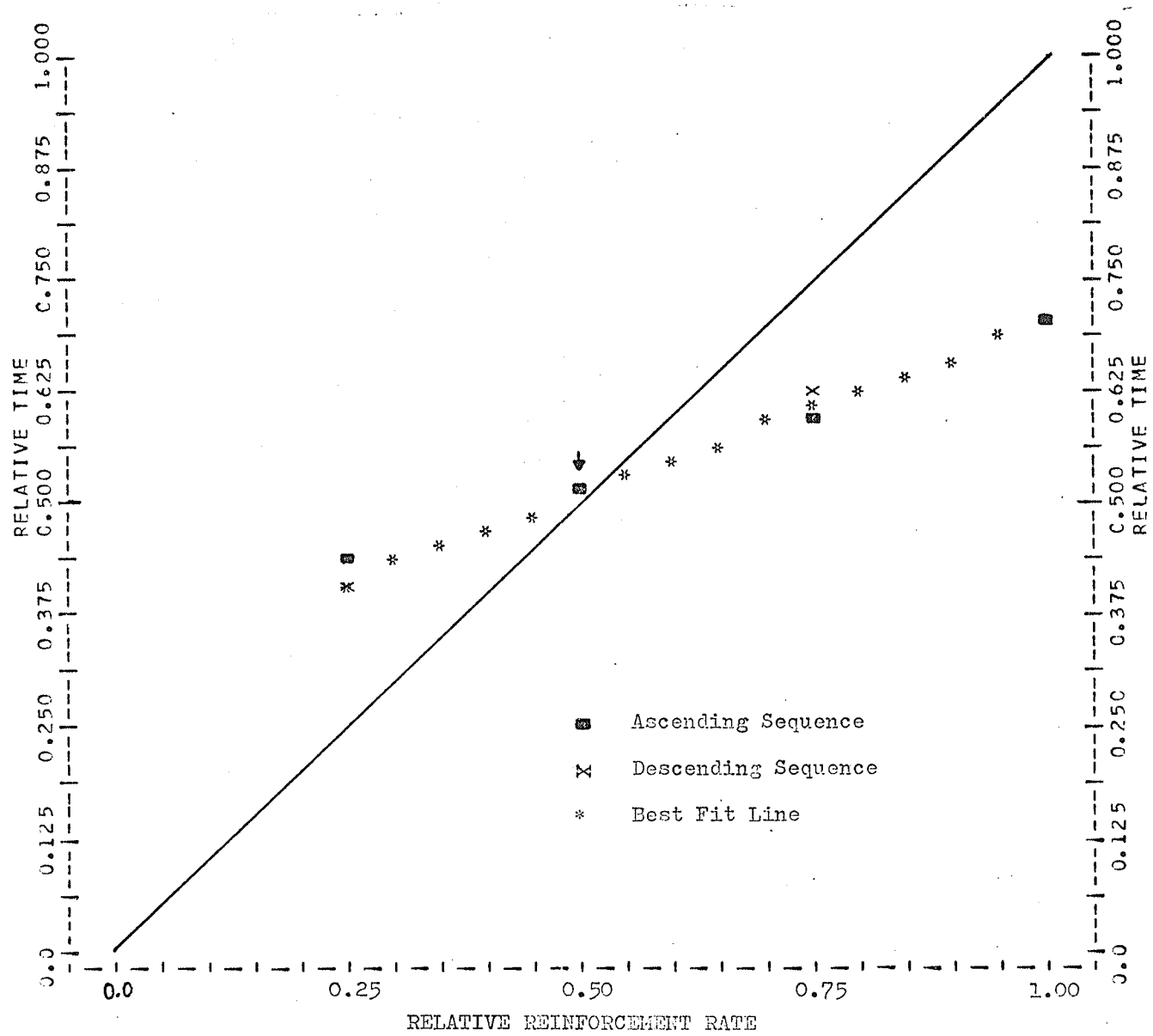


Fig. 14 Relative time as a function of relative reinforcement rate for Subject T-3. The second ascending and descending sequences are shown.

indicated by the horizontal line with zero slope in Figures 15 through 21. The best fit lines, calculated by means of the method of least squares, are also indicated. There appears to be no consistent difference between the first sequences, shown in Figures 15 through 20, and the second sequences, shown in Figures 19, 20, and 21.

There appears to be no obvious effect of the different changeover delays used (2 seconds for M-3 and T-1; 4 seconds for T-3 and T-4), nor of the different stimuli used in the final sequences (light on for M-3 and T-4 and light off for T-3).

Considering the changeover rate as a function of relative reinforcement rate, in the second descending sequence for M-3 (Figure 22), the changeover rate decreased as relative reinforcement rate diverged from .25. This is probably only a consequence of the two extra points. Otherwise, it would have followed the first of the two following patterns, which describe the rest of the data: (1) the changeover rate decreased as relative reinforcement rate increased from .25 to 1.0 (e.g., Figure 23, second ascending and descending sequences); (2) the changeover rate decreased as relative reinforcement rate diverged from .50 (e.g., Figure 22, first ascending sequence). Similar results were found by Stubbs and Pliskoff (1969) and Pear and Stevens (1971). There are two exceptions to the above. In both Figures 23 and 24, the changeover rate is lowest when the relative reinforcement rate is equal to .75 in the first ascending sequence. There appears to be a difference between the subjects with the 2-second COD and the 4-second COD in Figures 21 through 25. At almost all corresponding points, the changeover rate is higher for M-3 and T-1, the subjects exposed to the 2-second COD. There appears to be

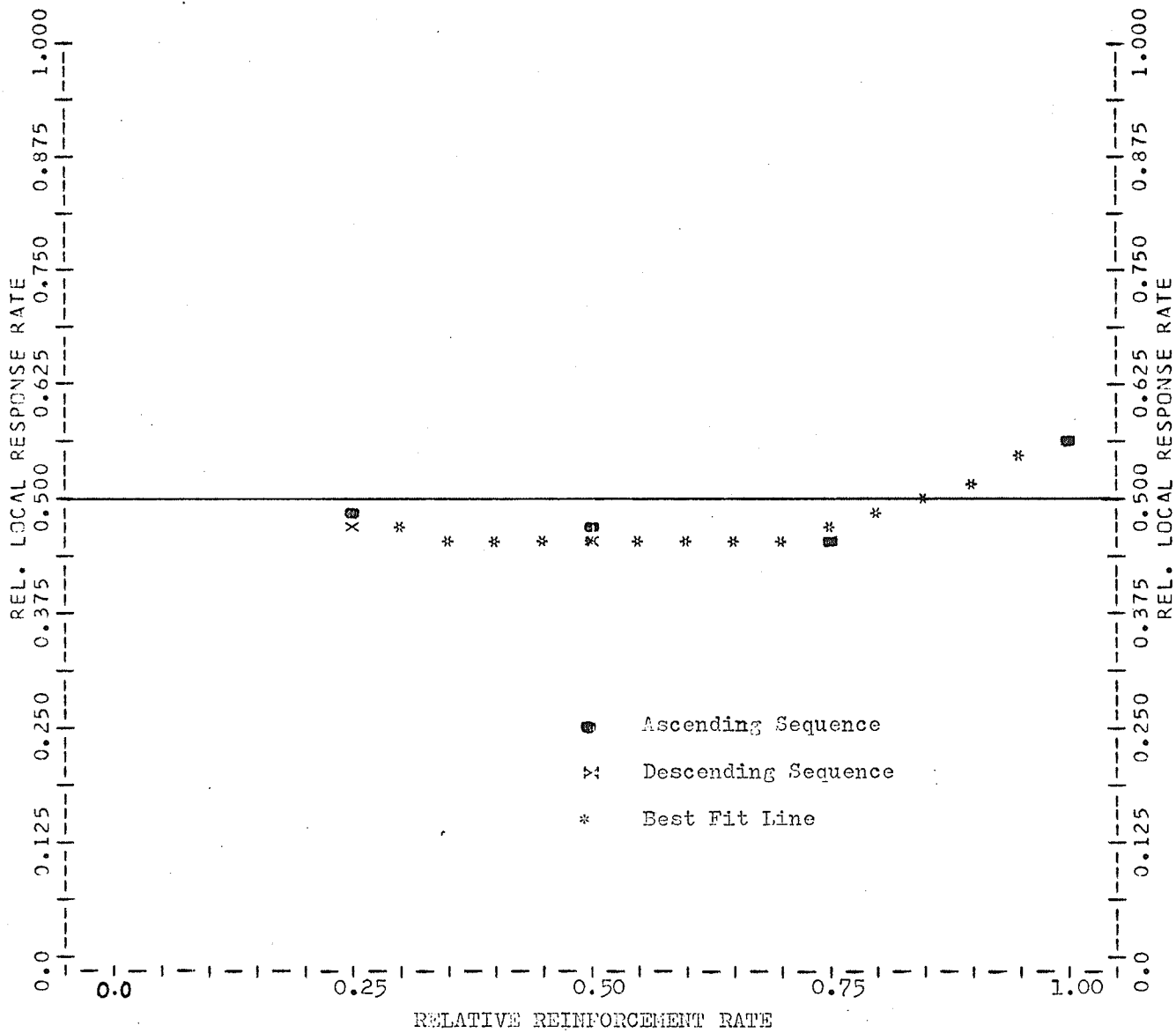


Fig. 15 Relative local response rate as a function of relative reinforcement rate for Subject M-3. The first ascending and descending sequences are shown.

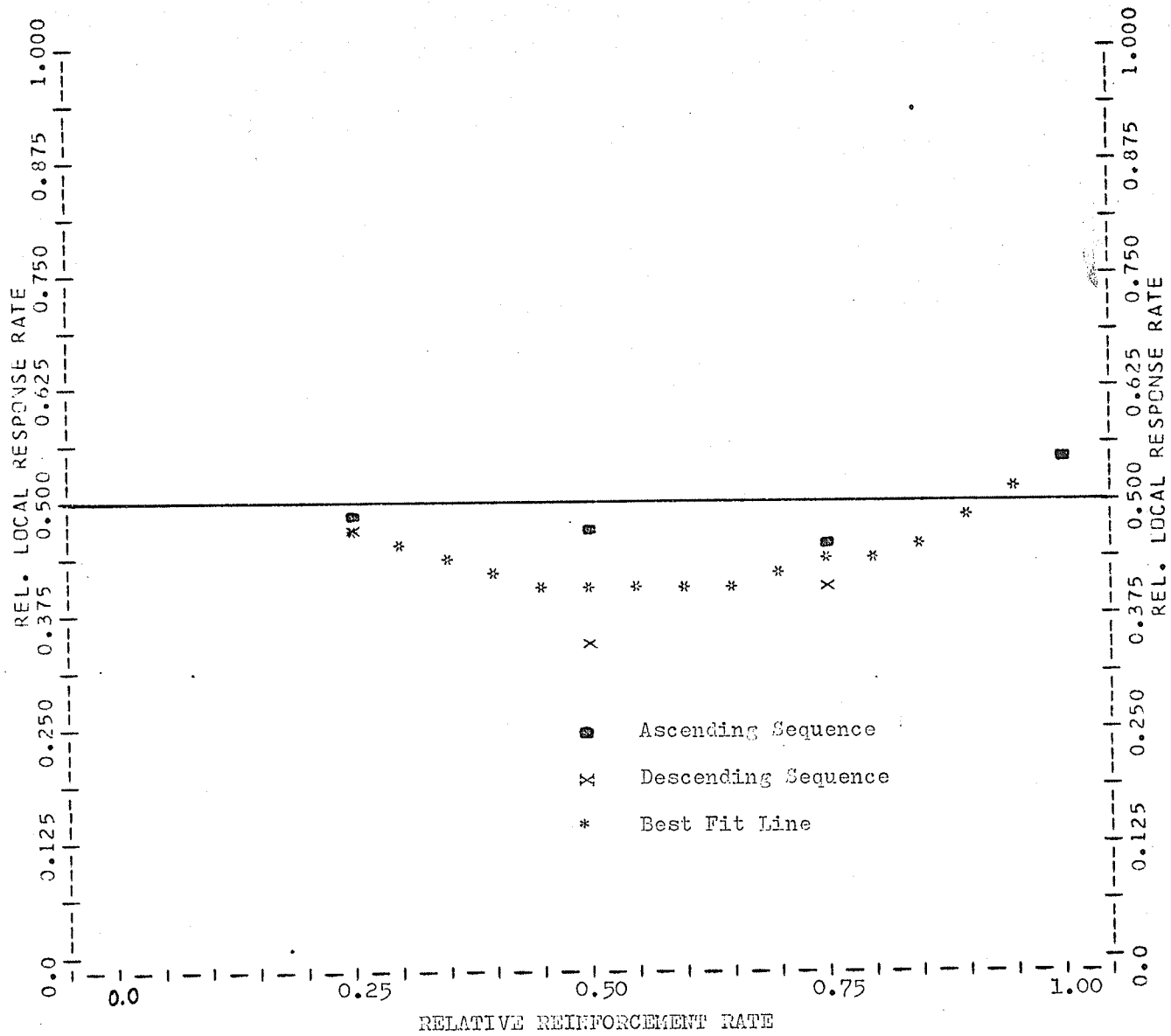


Fig. 16 Relative local response rate as a function of relative reinforcement rate for Subject T-4. The first ascending and descending sequences are shown.

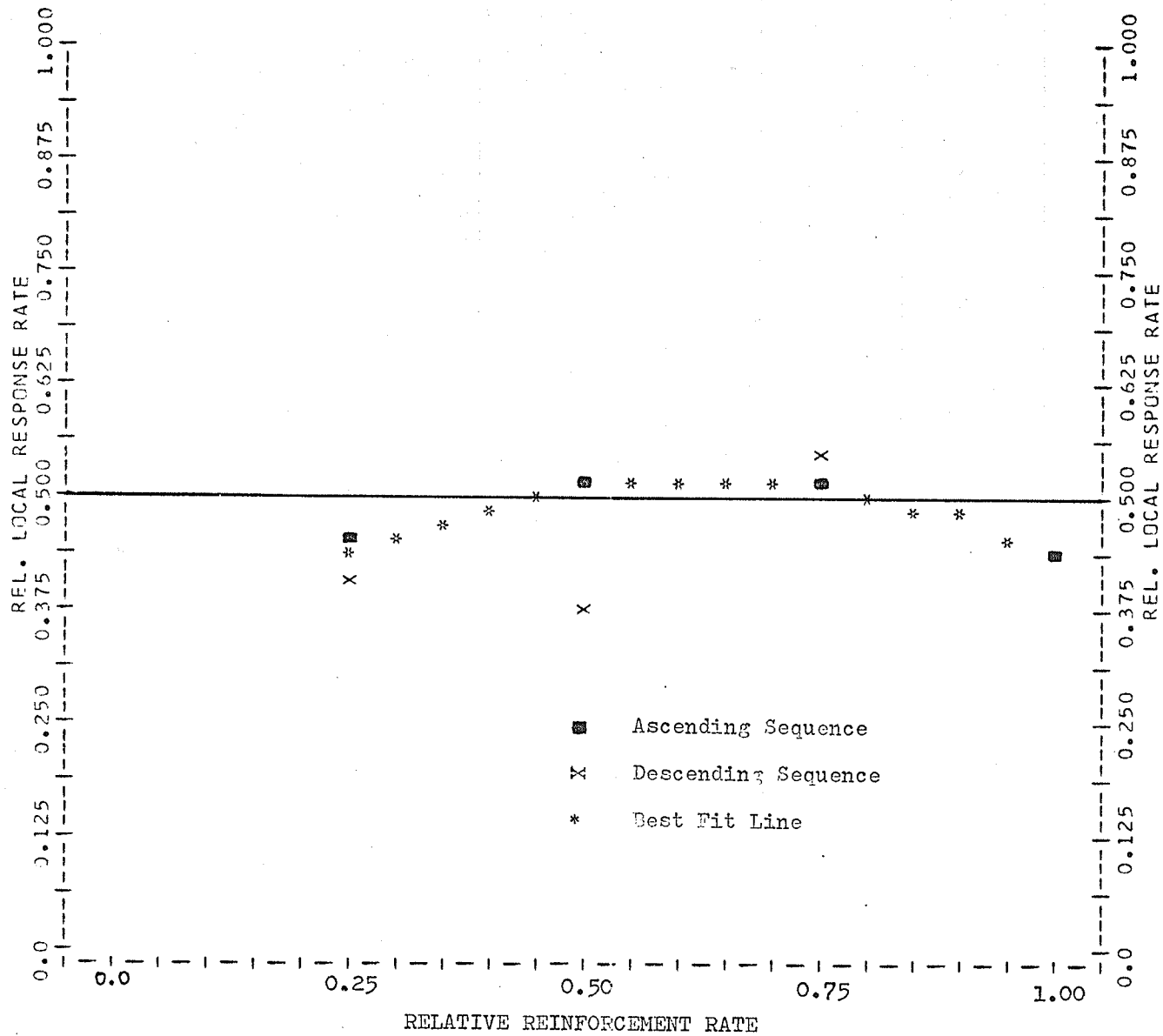


Fig. 17 Relative local response rate as a function of relative reinforcement rate for Subject T-1. The first ascending and descending sequences are shown.

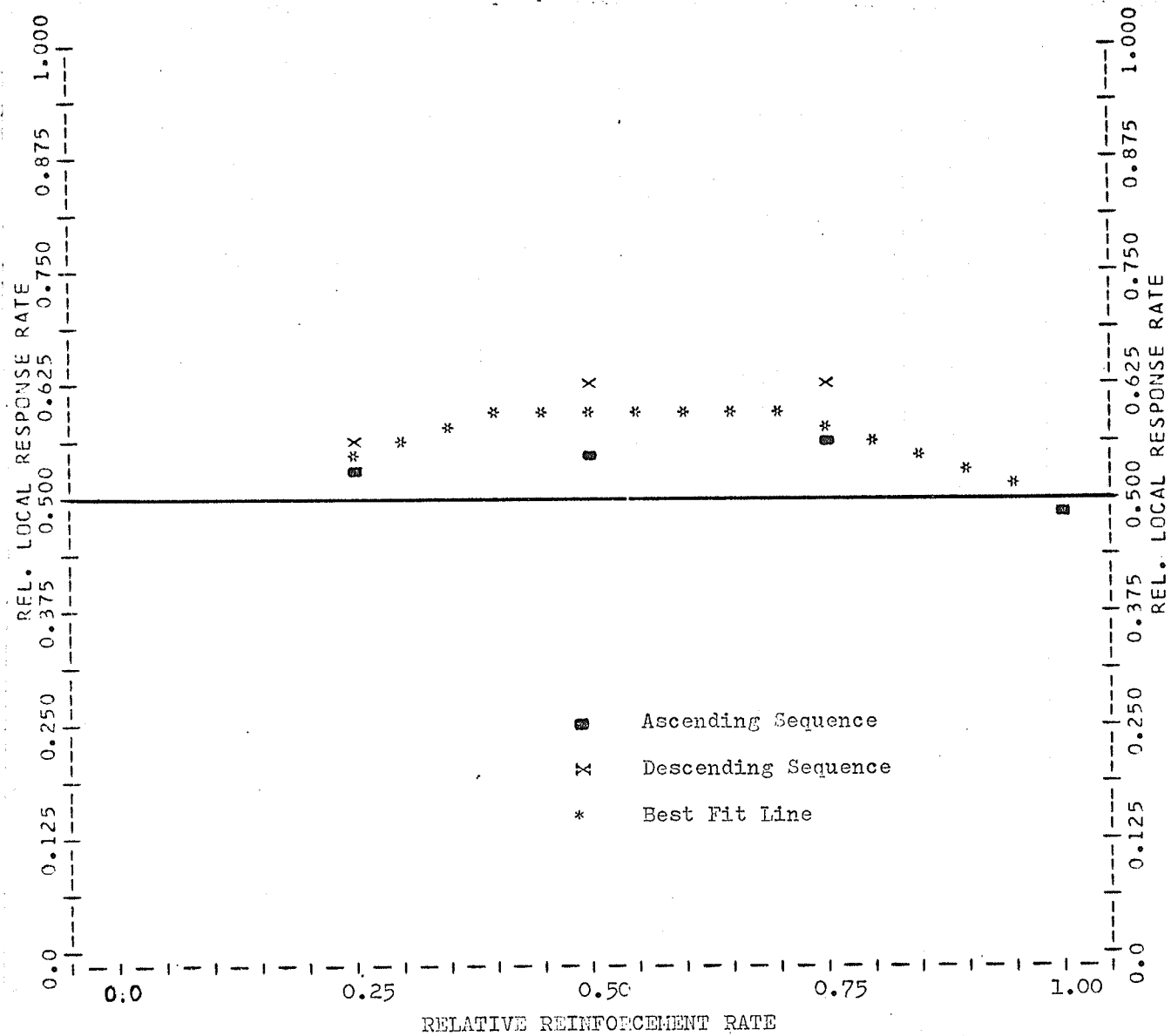


Fig. 18 Relative local response rate as a function of relative reinforcement rate for Subject T-3. The first ascending and descending sequences are shown.

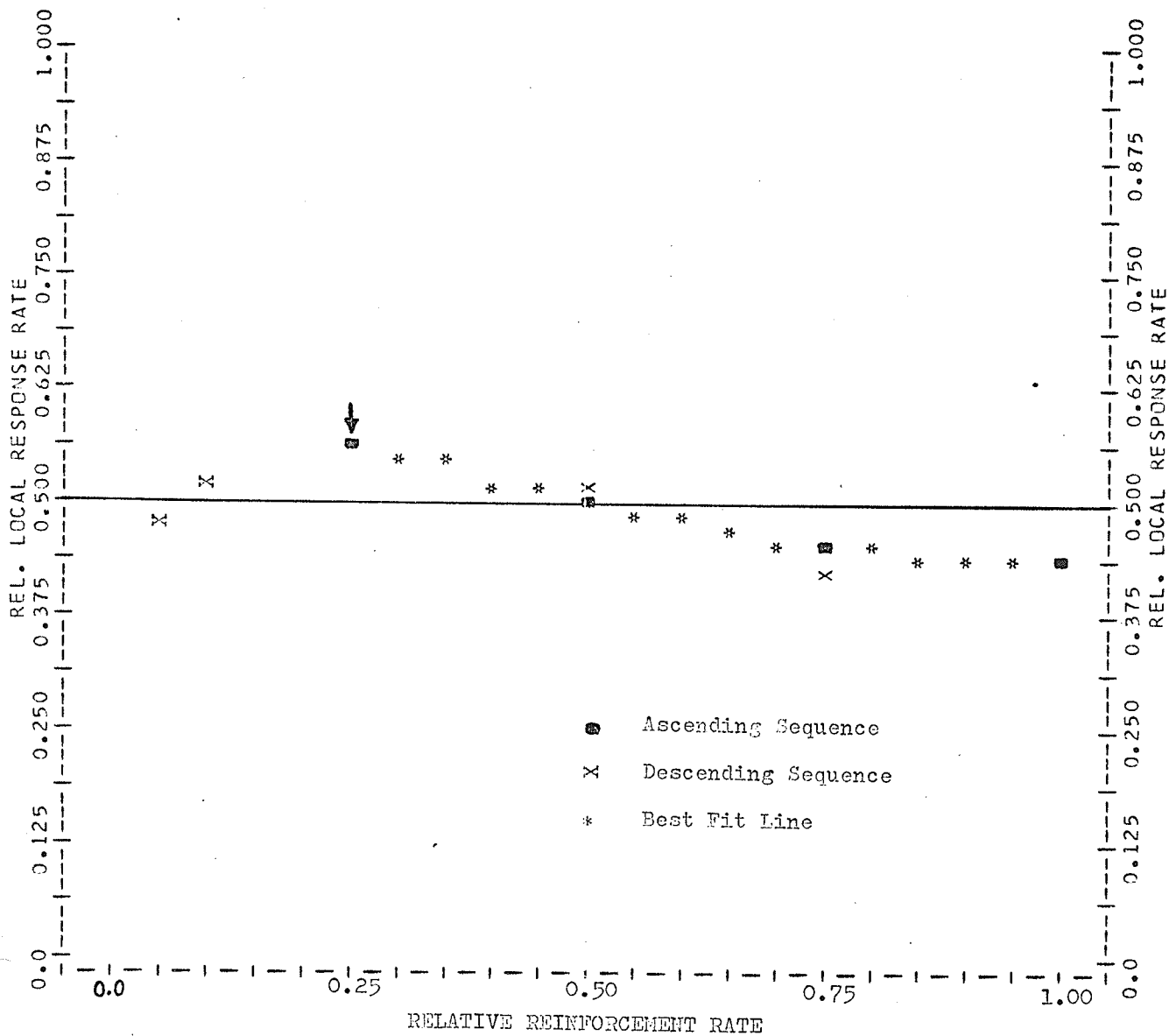


Fig. 19 Relative local response rate as a function of relative reinforcement rate for Subject M-3. The second ascending and descending sequences are shown.

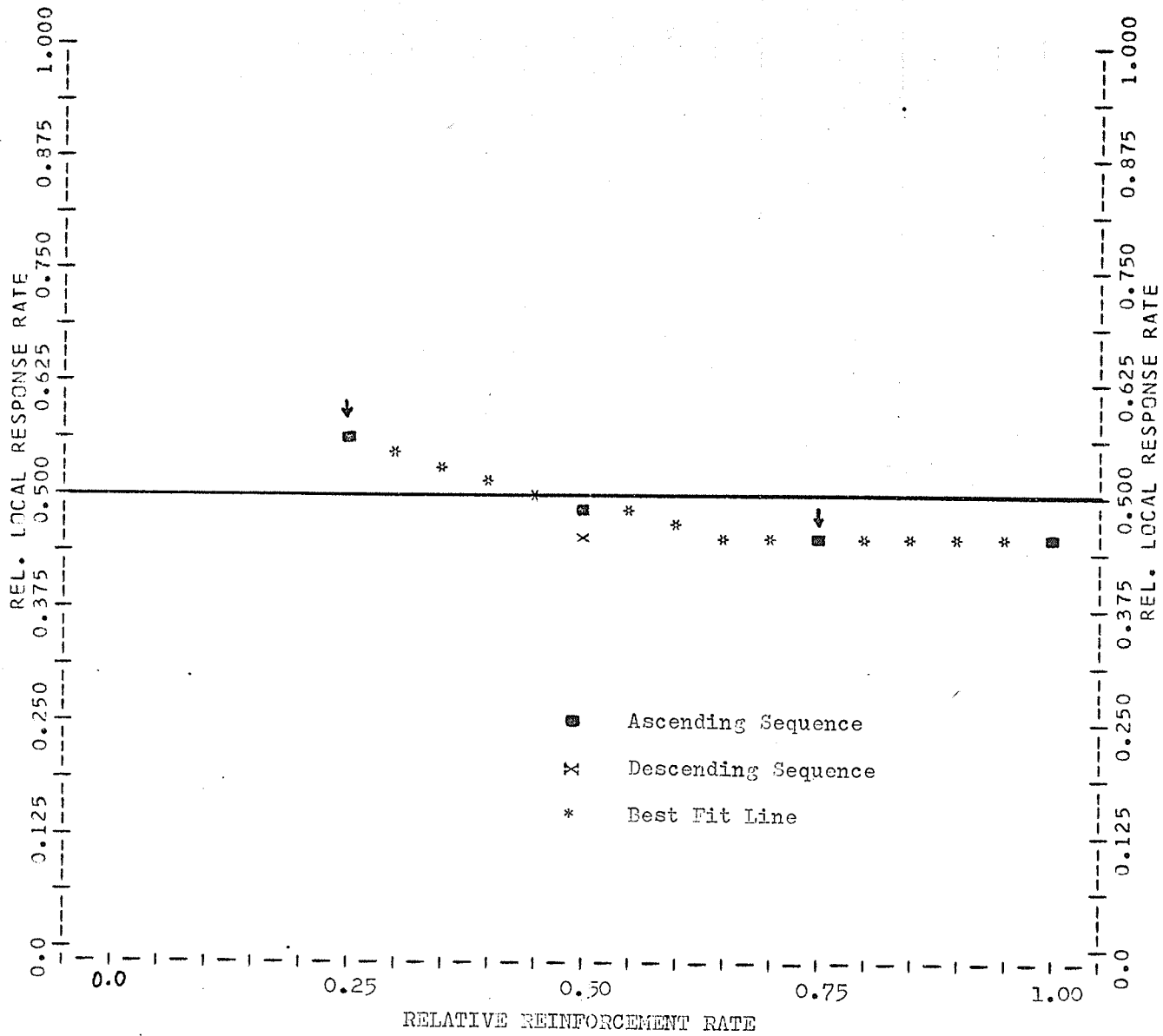


Fig. 20 Relative local response rate as a function of relative reinforcement rate for Subject T-4. The second ascending and descending sequences are shown.

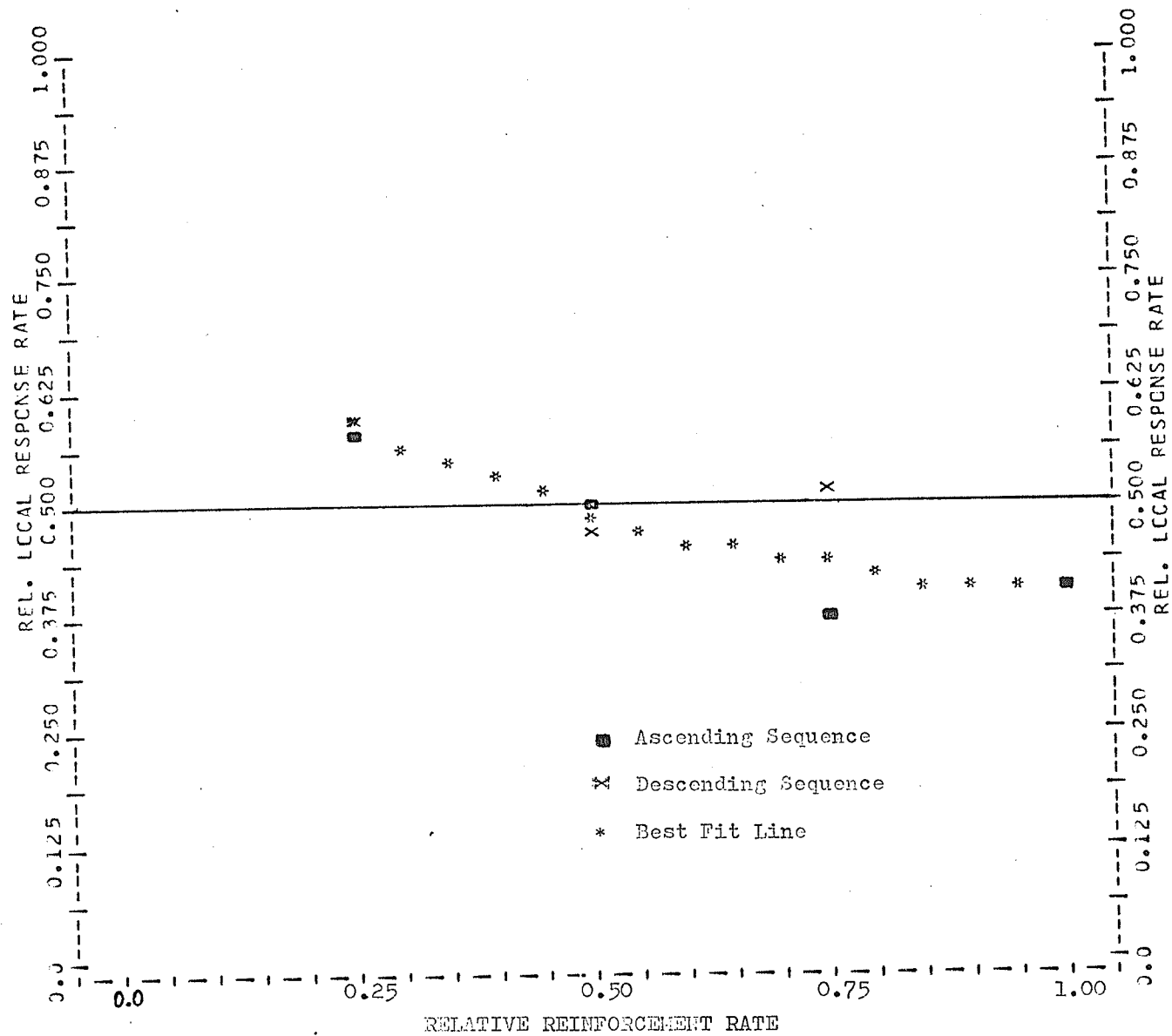


Fig. 21 Relative local response rate as a function of relative reinforcement rate for Subject T-3. The second ascending and descending sequences are shown.

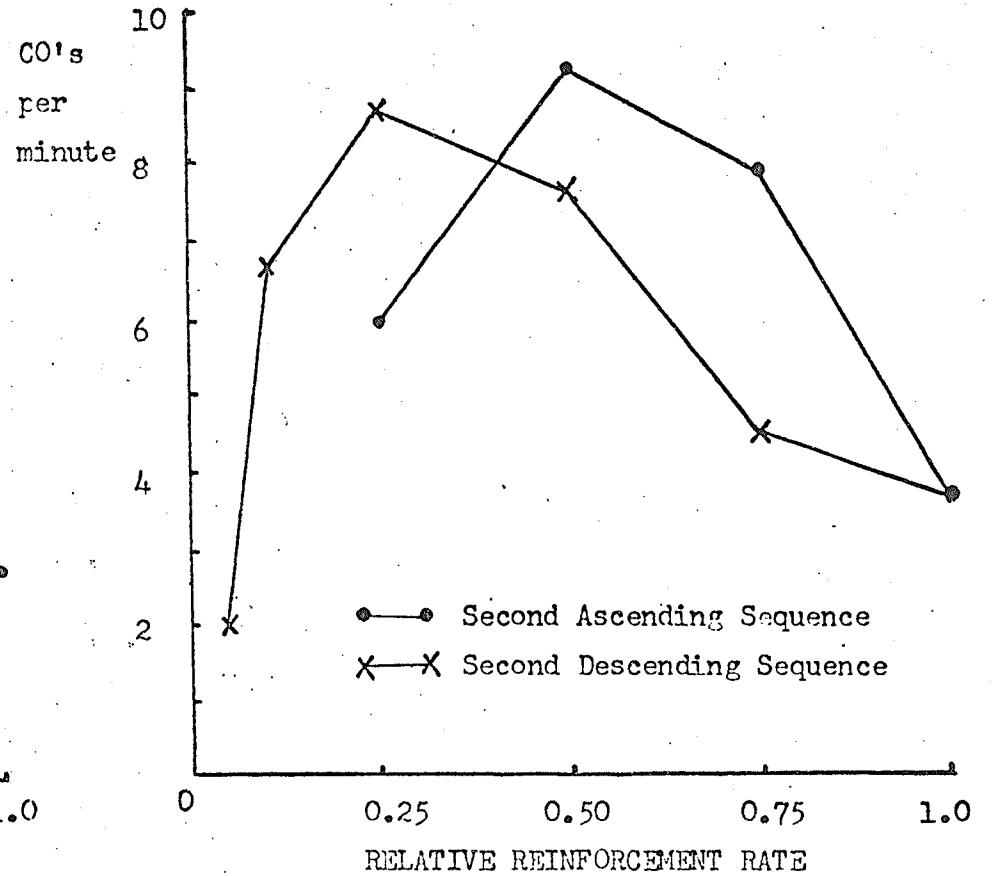
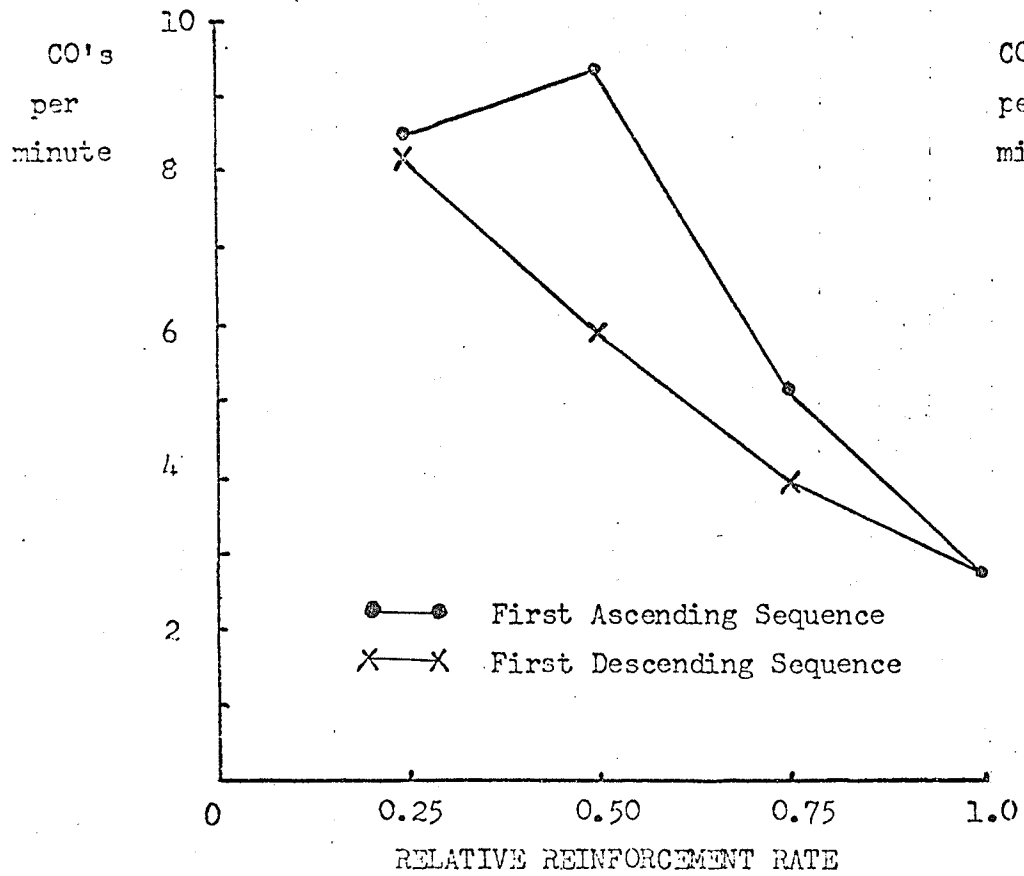


Figure 22. Changeover rate as a function of relative reinforcement rate for Subject M-3.

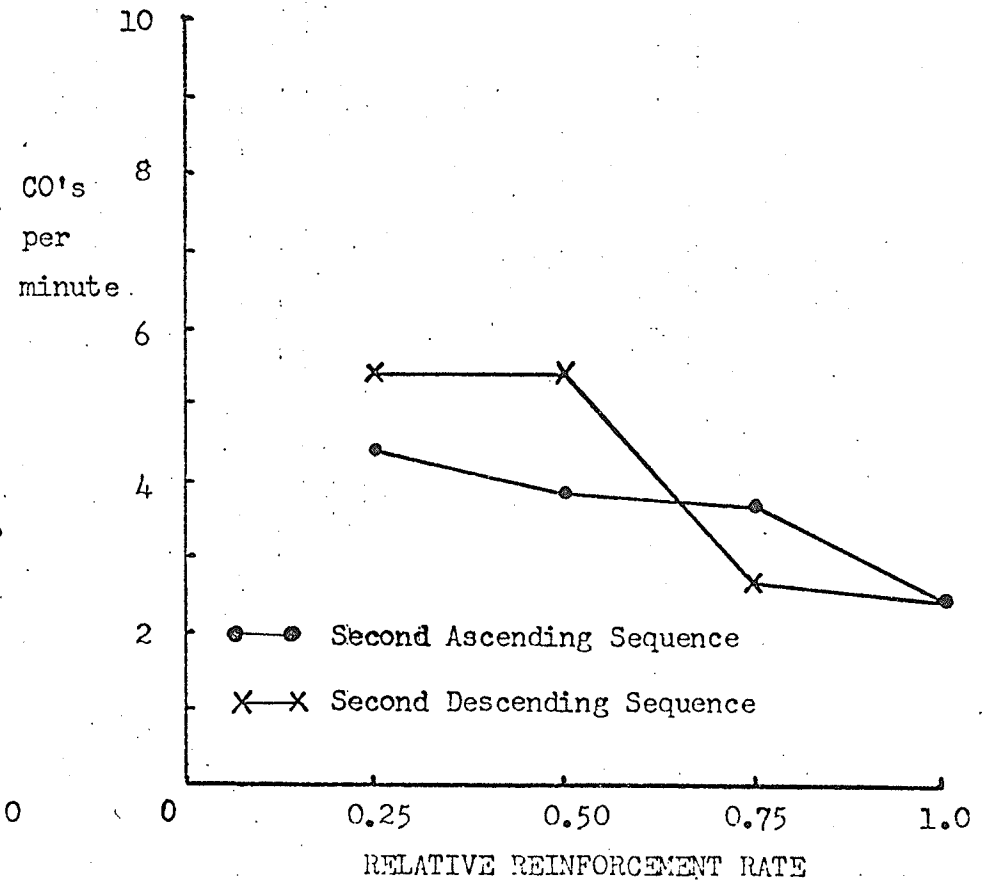
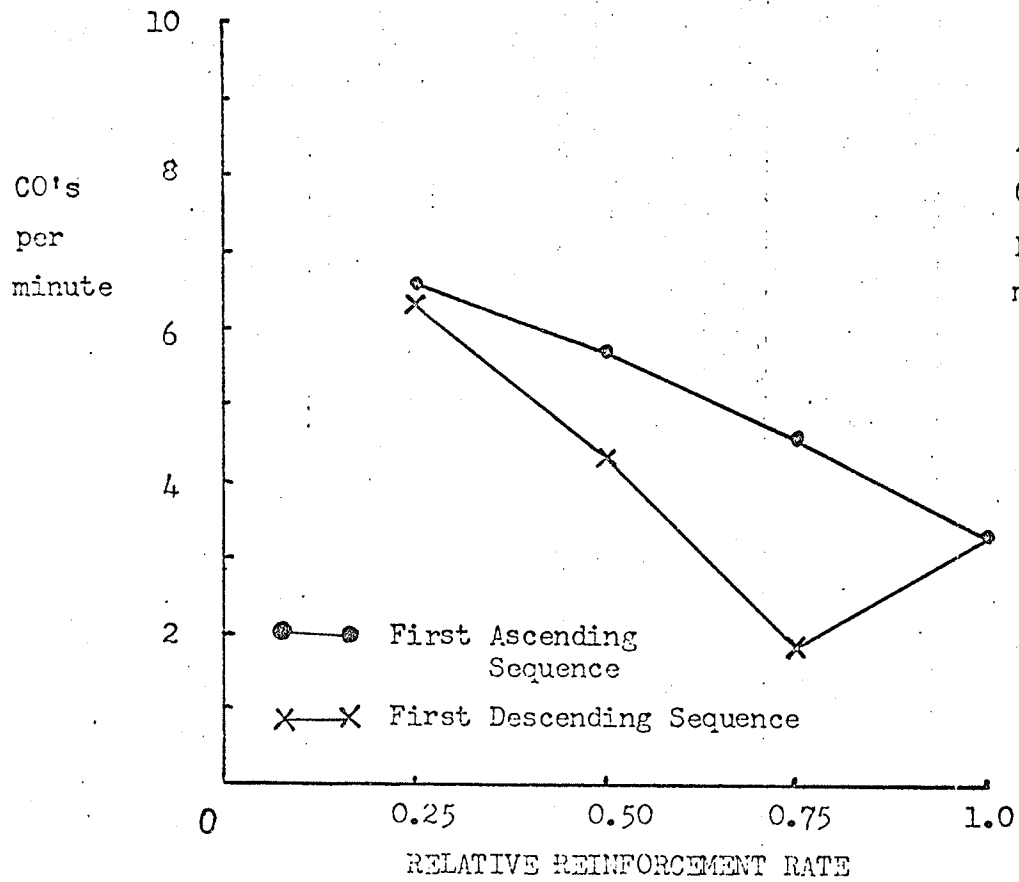


Figure 23. Changeover rate as a function of relative reinforcement rate for Subject T-4.

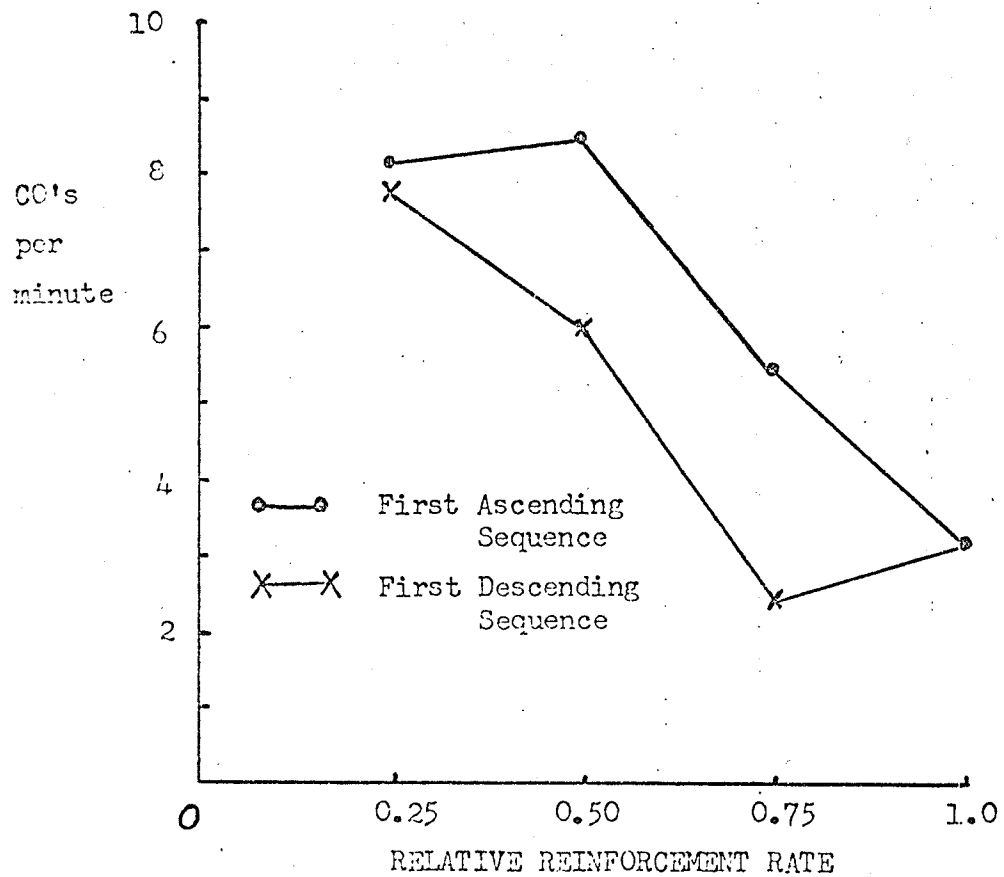


Figure 24. Changeover rate as a function of relative reinforcement rate for Subject T-1.

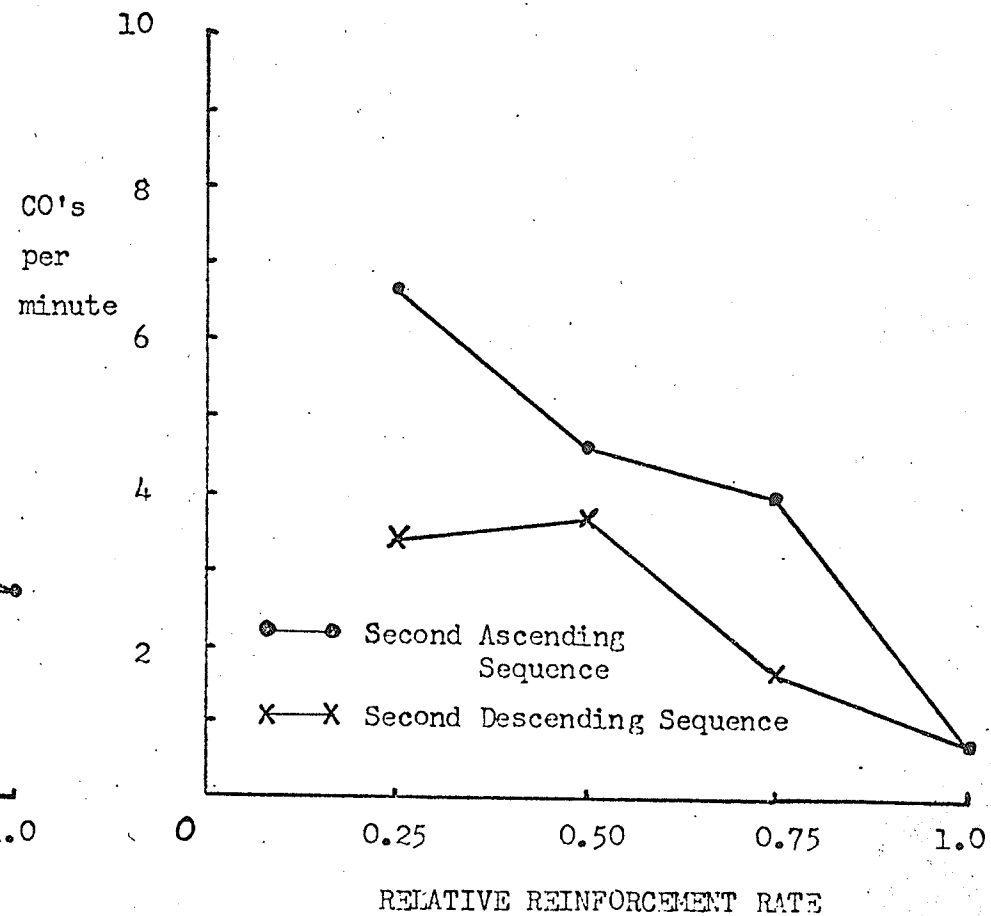
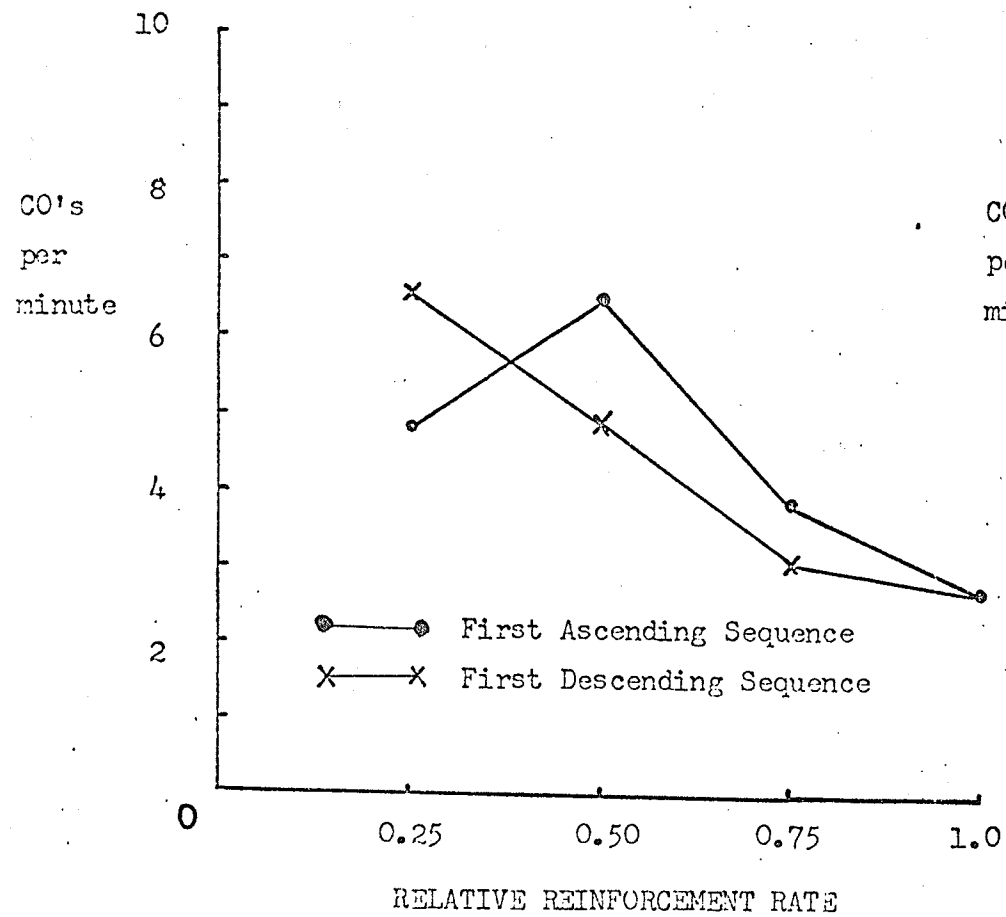


Figure 25. Changeover rate as a function of relative reinforcement rate for Subject T-3.

no effect of the stimulus (light on or light off) used in the second sequences. The COD data supports that obtained by Brownstein and Pliskoff (1968), Herrnstein (1961), Shull and Pliskoff (1967) and Stubbs and Pliskoff (1969), all of whom found changeover rate to decrease as a function of increases in the COD. (The above studies investigated effects of the COD duration within subjects rather than across subjects, as in the present experiment.)

CHAPTER VI
SUMMARY AND CONCLUSIONS

The major finding of this experiment was that the separate schedules of reinforcement must be correlated with separate stimuli of some sort for matching to take place unless the reinforcement density is high. When no separate stimuli were used, the relative measures approximated .50, except when there was an extremely high rate of reinforcement in one of the concurrent schedules and a low rate of reinforcement in the other. Under these conditions, it is possible that the reinforcement rates would serve as stimuli in a similar manner as the light did in the first sequences. It remains to be seen whether or not reinforcement rate could be used to generate a matching function throughout the entire range of relative reinforcement rates.

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