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Rats in Bliss: A Minimal-Deviation Model of Ratio Schedule Performance

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Running head: A MINIMUM-DEVIATION MODEL OF PERFORMANCE

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Abstract

The minimum-deviation theory predicts that an organism will seek to minimize the behavioral distance between an unconstrained baseline and constrained conditions caused by reinforcement schedules (Staddon, 1979). According to the performance model proposed by Allison (1983), behavior under scheduled constraint will come as close as possible to an unconstrained "bliss point" or behavioral ideal. The present study examined applications of these models to fixed ratio (FR) schedules. Six rats were first exposed to a paired baseline procedure to establish their individual bliss points. Each rat was then exposed to a series of two fixed ratio schedules: FR 2 and FR 10. The model failed to predict the response rates; rats pressed a bar consistently more often than predicted by the model. These results are consistent with an earlier study in our lab by Witte (1994), which failed to support the model on interval schedules. The results have implications for minimum-distance models of learning and performance.

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The quantitative analysis of operant behavior has been a focus of research in psychology for much of the latter half of the twentieth century. The early researchers sought to define reinforcement on a quantitative level within the constructs of operant conditioning. The law of effect as proposed by Skinner (1938) defined reinforcement on a functional level: reinforcers increase the rate of responding. According to Skinner, a reinforcer can be anything that serves to increase an organism's rate of responding to a level greater than its previous level. By the Skinnerian definition, when a reinforcer follows a response, the particular response will increase in frequency. On the contrary, failure to establish the increased response rate disproves the law of effect (Meehl, 1950). The theory has been criticized as non-falsifiable because of the circular definition of reinforcement dependent upon the particular experiment. The Skinnerian law of effect has formed the basis of modern quantitative models of operant responding and shaped the development of subsequent experimentation.

In an effort to define reinforcement in a falsifiable, non-circular manner independent of a specific experiment, Meehl (1950) developed the transituational theory of reinforcement. A situational reinforcer is a specific reinforcer which has been demonstrated to have conditioning power in a specific situation. Meehl's (1950) transituational hypothesis states that all situational reinforcers will be transituational. That is, a situational reinforcer will have reinforcing properties in all situations. Unlike Skinner's (1938) definition, Meehl's (1950) hypothesis is falsifiable. Specifically, it is falsified if a situational reinforcer is ineffective in certain response conditions (Premack, 1959, 1962).

Premack (1959) showed the reversibility of reinforcement by the rate differential hypothesis: a response with a higher independent rate of responding will serve as a reinforcer for a response with a lower rate of responding. According to the Premack principle, the relation of a reinforcer to a certain response can change based on the conditions of the contingency. This idea violates Meehl's (1950) theory of transituational reinforcement because a particular event will sometimes serve as reinforcement and at other times will not. Unlike prior definitions of reinforcement as a stimulus (Skinner 1938; Meehl 1950), Premack (1959) defined reinforcement as the opportunity to engage in a response. The rate differential hypothesis fundamentally changed the definition by reconceptualizing reinforcement.

Timberlake & Allison (1974) proposed the response deprivation theory of reinforcement as an alternative quantitative approach to instrumental performance.

According to the theory, a reinforcer can be anything that is constrained to a level below its baseline rate when the organism has free access to the reinforcer. Timberlake and Allison's (1974) theory is consistent with the Premack principle because activities with high independent response rates will reinforce activities with low independent response rates. However, Timberlake and Allison's (1974) model also predicts that an activity with a low rate of response can actually reinforce an activity with a higher response rate. According to the response deprivation theory, constraint of the animal's behavior is of key importance to the acquisition of reinforcement.

The concept of schedule constraint is a key element of Timberlake and Allison's (1974) response deprivation theory. Reinforcement schedules constrain an organism's reinforcement rate by requiring it to perform the instrumental response for access to the contingent response and reinforcer. The organism's behavior is also constrained by limitations of time because an increase in one activity must cause a decrease in some other activity (Staddon, 1979). The distributions of activities under free conditions is represented by a point, the free behavior point. According to Staddon (1979), the underlying mechanism of operant behavior is homeostasis or reaching an equilibrium. The minimum-deviation theory predicts that an organism will seek to minimize the relative behavioral distance between the unconstrained baseline response rate and the response rate under constraint of the reinforcement schedule (Staddon, 1979). According to the minimum-deviation model proposed by Allison (1983), behavior under scheduled constraint will come as close as possible to an unconstrained "bliss point" or behavioral ideal, as shown in Figure 1. This simple performance model predicts the functional relations obtained on ratio schedules, while incorporating the Premackian idea of the relativity of reinforcement. Several minimum-distance bliss point models have attempted to define and describe the relationship between response rate and reinforcement rate of operant conditioning (Allison, 1983; Staddon, 1979).

Most research on bliss-point models has employed ratio schedules of reinforcement, while differing on several other parameters, including the type of species used, the instrumental and contingent responses, levels of deprivation and the physical details of the apparatus (Allison, 1983; Staddon, 1979). During the typical minimum-deviation experiment, the animal is exposed to paired baseline sessions in which it is given free access to both the instrumental response and the contingent response for reinforcement. It is from the baseline procedure that the bliss point is established by plotting the number of reinforcers consumed as a function of the number of responses made. The bliss point thus represents the animal's unconstrained responding.

Introducing a ratio schedule of reinforcement constrains the organism's operant behavior below that of its baseline level during the free access condition. On a ratio schedule, the organism receives one reinforcer for each N responses. Behavior is restricted by a linear constraint line representing the relationship between response and reinforcement rates under that particular ratio schedule. Several constraint lines are also depicted in Figure 1. Minimum-distance models predict that response rate under scheduled constraint be described by equation 1:

$$x = \frac{a + cb}{c^2 + 1} \qquad (1)$$

Where x is the predicted response rate under scheduled constraint, a is the response rate in baseline, b is the reinforcement rate in baseline, and c is the slope of the constraint line. Responses on one bar (right) are plotted as a function of responses on the other bar (left) in Figure 1 for ratio schedules and Figure 2 for interval schedules. Usually, the constraint line lies below the animal's bliss point, so the animal cannot reach the optimal level under the constraint of the ratio schedule. According to the bliss point models of performance, the animal will respond at a rate which will minimize the distance from the constraint line to the bliss point. The predicted rate of responding is also depicted in Figure 1.

Applications of bliss point models to interval schedules have proven to be more difficult. One of the problems is that the schedule constraint line is nonlinear on an interval schedule, making the minimum deviation function difficult to define (see Figure 2). There has been disagreement about the correct formulation of the schedule constraint line, which is commonly called a feedback function on an interval schedule. Several feedback functions have been proposed over the years (Baum, 1973; Nevin & Baum, 1980; Prelec, 1982; Staddon & Motheral, 1978). While differing in the basic assumptions and free parameters, each model describes the rate of reinforcement on the interval schedule as a function of the rate of responding.

Using the feedback function proposed by Baum, Witte (1994) examined a minimum deviation bliss point model for responding on a simple interval schedules of reinforcement. According to Baum (1973), the schedule constraint line for interval schedules is given by equation 2:

$$r = \frac{1}{t + 0.5\,(1/B)} \qquad (2)$$

Where r is the rate of reinforcement produced by a variable interval schedule, t is the average scheduled inter-reinforcer interval, and B is the rate of response.

Baum's equation was selected because it is relatively simple mathematically and has no free parameters. As shown in Figure 3, the model failed to predict the rate of responding in the Witte (1994) application. On each simple interval schedule, the actual number of responses far exceeded that predicted by the minimum-deviation model.

It is unusual that the Witte study of the application of performance models to interval schedules did not support the minimum-deviation model because such models have been supported on ratio schedules in previous experiments, and it would be expected that these models would generalize to other schedules of reinforcement. Interval and ratio schedules of reinforcement have not been directly compared within the performance models. Thus, it would be interesting to replicate the Witte (1994) experiment using ratio schedules. The present study sought to substantiate the findings of the previous experiments involving performance models of behavior as a useful tool to predict an animal's performance. Using ratio schedules like those of Allison (1983) in conjunction with the apparatus and parameters employed by Witte (1994), an evaluation of the minimum-distance bliss point model of ratio schedule performance was conducted. The study intended to determine if the nature of Witte's (1994) apparatus and parameters, rather than the use of interval schedules, caused the failure of the models. Rats were exposed to a series of fixed ratio schedules of reinforcement after exposure to unconstrained paired baseline sessions. The minimum-deviation model predicts that the animal's response rate would minimize the distance between the organism's optimal behavioral ideal (or bliss point) and the constraint line imposed by the ratio schedule.

Method

Subjects

The subjects were six Sprague-Dawley rats obtained from Harlan Sprague-Dawley Laboratories in Indianapolis, Indiana. They were housed in the animal colony at Illinois Wesleyan University. The subjects were experimentally naive and approximately six months old at the start of the experiment. Each rat was individually housed and maintained at 80% of its ad libitum weight, with water freely available at all times in the home cage.

Apparatus

The apparatus consisted of a standard operant conditioning unit for rats (BRS/LVE Model RTC-028), measuring 30 cm in length, 24 cm in width and 26.5 cm in height. The ceiling and two side walls were Plexiglass, the front and back walls were stainless steel, and the floor was a wire grid.

The front wall contained two standard retractable response bars, 3 cm wide, projecting 2.5 cm into the chamber. The bars were centered in the front wall, 3 cm from the nearest side wall and 5 cm from the floor. When the bars retract, they were flush with the front wall. Both retractable bars were used during the study. The front wall also contained a food cup, extending 1.5 cm into the chamber, located 11 cm from the right wall and 2 cm from the floor. A bank of three cue lights (red, white and green) was located 5 cm above each bar. The individual lights in the bank were 2 cm apart (center to center). A third 5-W bulb, located in the upper left corner of the ceiling, served as a houselight.

The entire apparatus was enclosed in a sound-attenuating chamber, with masking noise provided by the exhaust fan. All experimental events and all data collection were controlled by an IBM PC-compatible computer connected to a MED Associates interface and running MED-PC software. The computer and interface were located in an adjacent room.

Procedure

All subjects were deprived to 80% of their ad libitum weights, and were shaped by hand to press both response levers. The experiment proper started when all animals were reliably pressing the levers for food. All subjects were first exposed to a paired baseline procedure, during which both levers were inserted into the chamber. Responses to the left bar produced a single 45 mg Noyes pellet, while responses to the right had no consequence. Each session lasted 25 minutes. A total of 5 baseline sessions were conducted.

Following the baseline procedure, each rat was exposed to a series of two fixed ratio schedules (FR 2 and FR 10). In experimental procedures, responding to the right bar was necessary to gain access to the left bar. Responses on the left were on a fixed ratio schedule of reinforcement (FR 1), meaning a single response on the left bar produced a Noyes pellet. Each schedule was used for ten consecutive days. Throughout every phase of the experiment, postfeeding occurred when the animal was returned to the home cage.

Results

Bliss points were calculated for each of the six rats by taking the average of responding on each bar during the baseline phase. From these, predicted response rates were calculated according to equation 1. Responses on one bar (right) are plotted as a function of responses on the other bar (left) in Figure 4 for FR 2 and Figure 5 for FR 10. The "predicted point" represents the minimum spatial distance between the constraint line and the bliss point. The "actual" point represents the animals actual behavior on the FR 2 and FR 10 schedules. The bliss point, the predicted response point and the actual response point are depicted graphically along the FR 2 and FR 10 constraint lines. As seen in Figure 4 and Figure 5, the rats' actual rates of responding to the right bar far exceeded the number predicted by the minimum-deviation model. The results are consistent across all six animals and ratio schedules used in the study.

Discussion

The present study examined minimum-distance models of ratio schedule performance. It was expected that the present experiment would support the minimum deviation model of performance. However, the results substantiate the earlier findings of the Witte (1994) study. The animals did not minimize the behavioral distance to the bliss point from the ratio schedule constraint line on either fixed ratio schedule. Instead, the actual number of responses far exceeded that predicted by the model. The findings contradict those of earlier studies involving bliss-point models of performance on ratio schedules.

Several hypotheses could explain the failure of the minimum-deviation models to predict performance on ratio schedules in the present study. Although such models have been successful on ratio schedules (Allison, 1983), the instrumental responses and reinforcement used were different from those used in the present study and the Witte (1994) study. While we used lever pressing to gain access to a food pellet, tube licking for water and pursuit behavior were used in previous studies (Staddon, 1979 and Allison, 1983). Perhaps the response parameters contributed to the failure of the bliss point model.

Another possible explanation, could be the relative "behavioral cost" of the reinforcer. The FR 2 schedule may have been too easily attainable for the individual animals. Raising the "cost" of the reinforcer may support the prediction of the minimum-deviation models. The rationale is that a high required rate of responding would contribute to more efficient responding by the rat in order to maximize the amount of the reinforcer. Responding on the FR 10 schedule also far exceeded that predicted by the model. That the relative "cost" of the reinforcer on a FR 10 is too low, is a possibility. At higher ratio schedules of reinforcement, perhaps the rats' performance would come closer to that predicted by the model. A continuation of the present study might examine higher FR requirements.

Another possible explanation of the failure of the minimum-deviation models could be attributed to the "economic condition" to which the rats are exposed. Earlier studies took place in closed economies, meaning that the animals lived in the operant chamber and received food only by lever pressing. Performance has been shown to be influenced by prefeeding the animals (Staddon, 1979 and Allison, 1983). Returning the rats to the home cages and postfeeding may have affected the rates of responding to the right bar. Thus, the minimum-deviation models may be ineffective at predicting ratio schedule performance within an open economy.

Future research in the area of performance models of behavior should examine more closely the parameters employed in previous studies. For example, the specific instrumental and contingent responses used, the nature of the reinforcer and the economic conditions inherent to study. In addition, further research could investigate the effect of a closed economy, thus making it more like the "real world". Other studies could focus on the conditions in which performance is ideal and behavior is minimized according to these bliss-point model of ratio schedule performance.

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Figure Captions

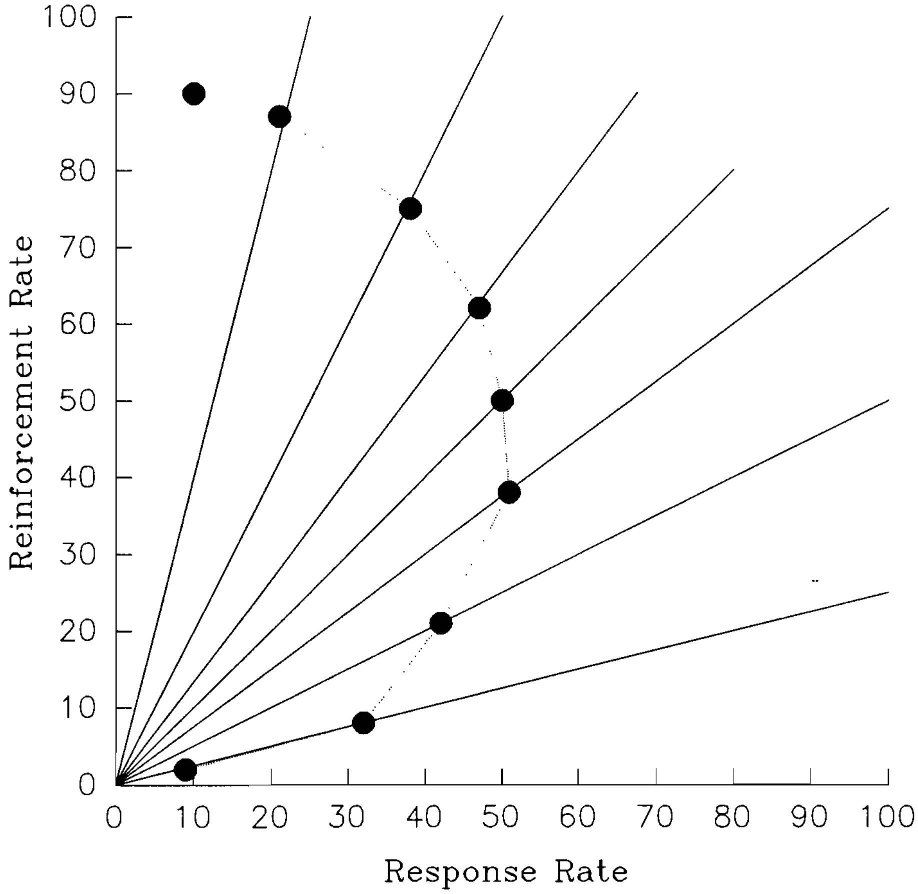
Figure 1. Reinforcement rate plotted as a function of the response rate showing the linear constraint lines of several fixed ratio schedules. The hypothetical bliss point and the minimizing points are also plotted.

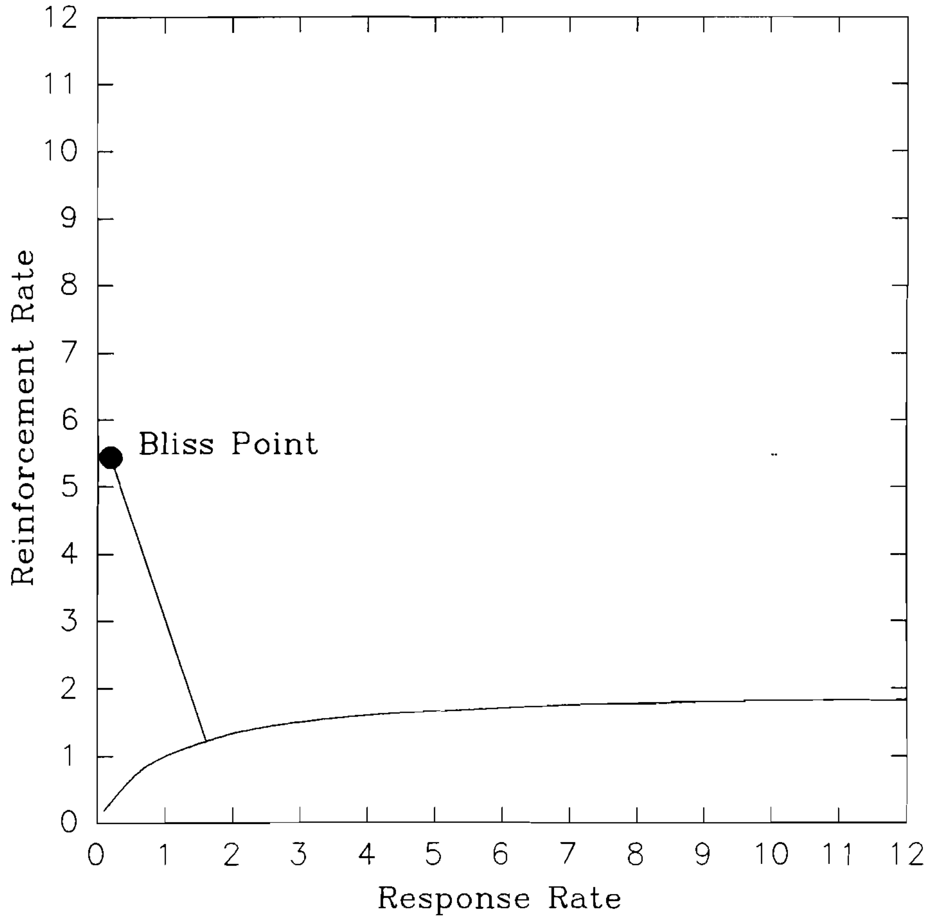
Figure 2. Reinforcement rate plotted as a function of the response rate showing the hyperbolic function of a hypothetical variable interval schedule. The bliss point and minimizing line from the point to the constraint line are also plotted.

Figure 3. Witte data of a single subject on a VI 30 second schedule with response rate on the left bar plotted as a function of response rate on the right bar. The bliss point, minimizing point on the constraint line, and the actual point from the data.

Figure 4. Present study data for individual subjects on a FR 2 schedule with response rate on the left bar plotted as a function of response rate on the right bar. The bliss point, minimizing point on the constraint line, and the actual point from each subject are shown

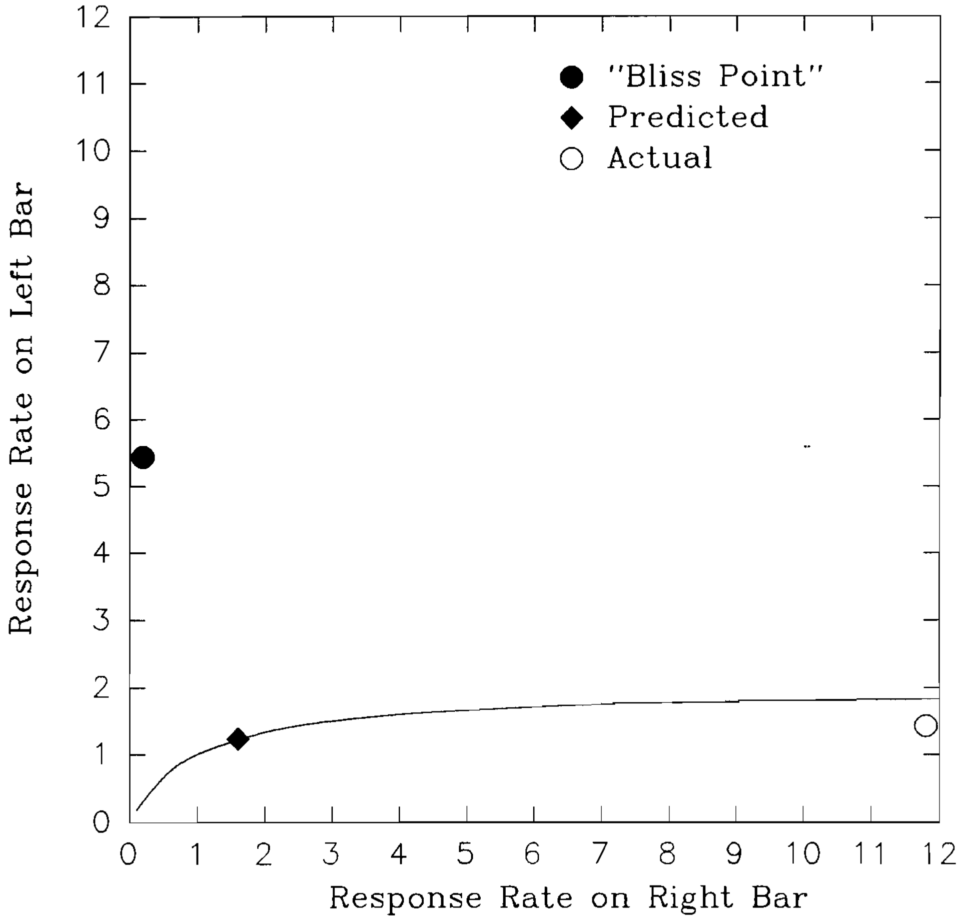
Figure 5. Present study data for individual subjects on a FR 10 schedule with response rate on the left bar plotted as a function of response rate on the right bar. The bliss point, minimizing point on the constraint line, and the actual point from each subject are shown.

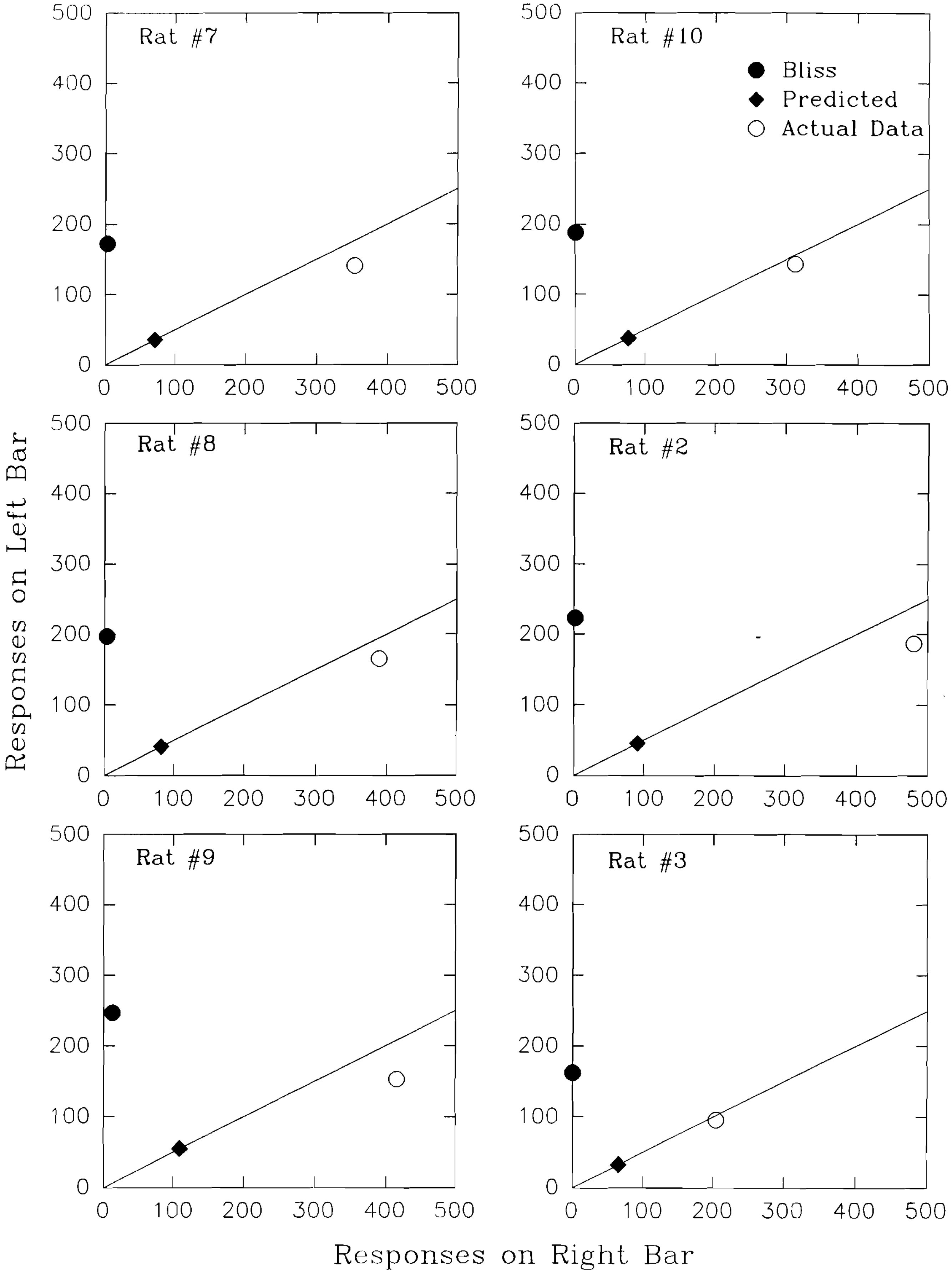

100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Reinforcement Rate
Response Rate



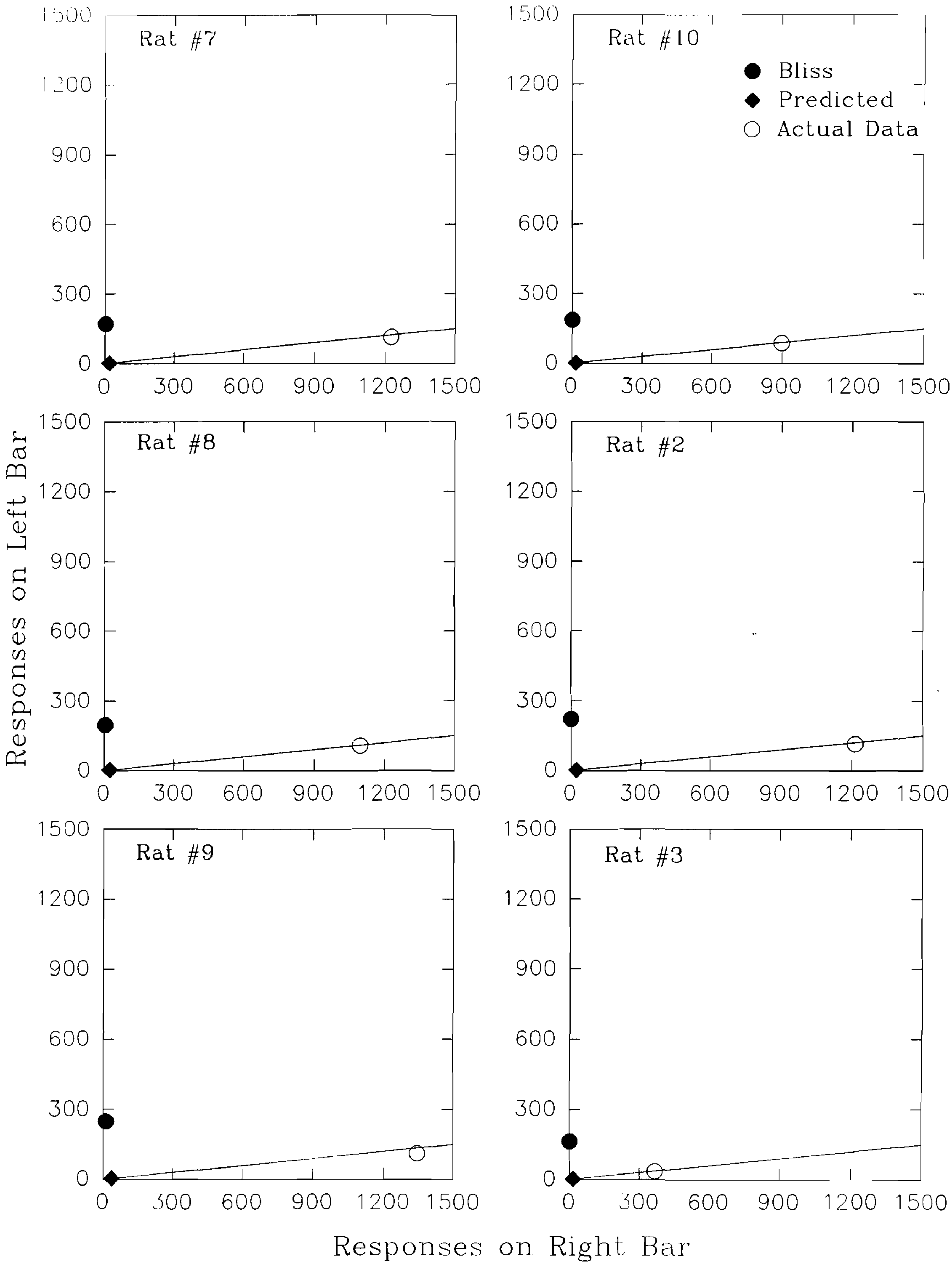
Reinforcement Rate
Response Rate
Bliss Point
0
1
2
3
4
5
6
7
8
9
10
11
12

VI 30 sec schedule





Rat #7
Rat #10
Bliss
Predicted
Actual Data
Rat #8
Rat #2
Rat #9
Rat #3
Responses on Left Bar
Responses on Right Bar
0
100
200
300
400
500



Rat #7
Rat #10
Bliss
Predicted
Actual Data
Rat #8
Rat #2
Rat #9
Rat #3
0
300
600
900
1200
1500
Responses on Left Bar
Responses on Right Bar