

PAIRED BASELINE PERFORMANCE AS A BEHAVIORAL IDEAL

JAMES ALLISON

INDIANA UNIVERSITY

Several recent theories view performance under the constraints of a schedule as an attempt to approach the basepoint, the total amount of the instrumental response and the total amount of the contingent response seen in the absence of schedule constraint. Some new analyses of experiments on concurrent ratio schedules, and simple ratio schedules offering an optional magnitude of contingent reward, tested this view directly. In each of the five experiments examined the organism rejected the chance of a closer approach to the basepoint, and thereby failed in addition to maximize the rate of reinforcement.

Key words: paired baseline, performance theory, maximization, concurrent schedule, ratio schedule, lever press, key peck, rats, pigeons

Several theories of performance under the constraints of a contingency schedule begin by assuming that the organism under study has some preferred amount of each of the responses controlled by the schedule. Several assume specifically that the organism prefers the amounts performed when freed from the schedule constraints, as, for example, the amounts of lever pressing and drinking done in a paired baseline condition with lever and water both freely available throughout the experimental session (Heth & Warren, 1978; Mazur, 1975; Rachlin & Burkhard, 1978; Staddon, 1979; Timberlake, 1980; Timberlake & Allison, 1974). This paper presents a new analysis of recent experiments which calls into question the widespread notion that paired baseline performance reveals the organism's behavioral ideal.

The conventional fixed-ratio schedule requires a fixed amount, I , of instrumental responding for each access to a fixed amount, C , of the contingent reward. Because of this constraint the schedule guarantees that the amount of reward obtainable per unit of instrumental responding cannot exceed the a priori ratio C/I . If the baseline ratio of the same two responses, O_c/O_i , happens to exceed C/I , the schedule therefore precludes attainment of the baseline levels of responding. Figure 1 shows these constraints graphically, plotting the total amount of response c against the total amount

of response i observed in the experimental session. Each unfilled circle represents the baseline amounts of the two responses, and each upward line, with slope C/I , represents the constraints of a particular schedule. Filled circles represent performance under the schedule; they cannot rise above or fall below the line of schedule constraint if the experimental procedure prevents overshooting of I and C .

In Figure 1, which takes Staddon's (1979) theory as a representative example, Panel A shows how the organism should perform under three different schedules by minimizing its deviation from the paired baseline levels of responding, assuming that the organism assigns equal weights to the two responses. If the two responses have equal weight, the closest the organism can come to the basepoint is the distance along a line from the basepoint to the right-angle intersection with the line of schedule constraint. Panel B shows what would happen if the organism weighted response c slightly more than response i (angle b is acute), and Panel C shows the opposite case (angle c is obtuse).

The usual approach to testing this group of theories involves the measurement of performance under several different schedules in an effort to see whether the empirical function has one of the several curvilinear shapes allowed by the theory. Complications arise because the theory typically gives no clue in advance as to the exact shape of the function to be expected in any particular experiment. Quantitative goodness of fit, tested successfully

Send reprint requests to: James Allison, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

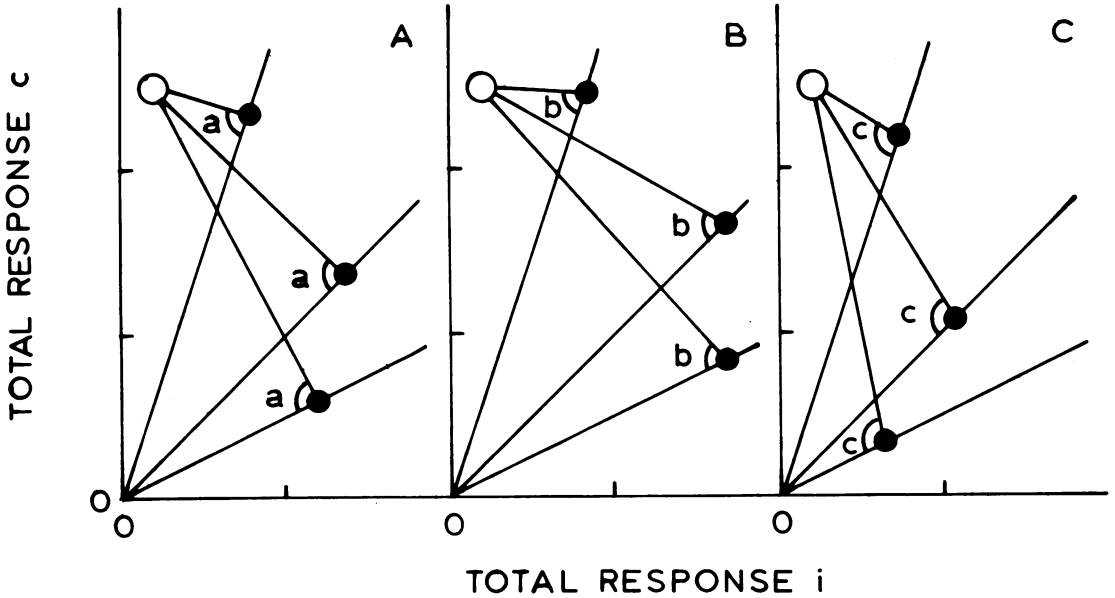


Fig. 1. Experimental and theoretical constraints on performance under simple fixed-ratio schedules. Unfilled circles represent performance under the paired baseline condition. Filled circles represent performance under the constraints of three different schedules, assuming that the organism minimizes its deviation from the basepoint. In Panel A the two responses are weighted equally. Response *c* is weighted more heavily in Panel B, response *i* more heavily in Panel C.

after the fact, may comfort the theorist but convert few skeptics. Should the test show no significant nonlinear component, the theorist in turn may claim that a wider range of schedule values might have revealed the expected nonlinear component. Uncertainty may cloud even the ordinal predictions. Asked to rank order the three schedules on the predicted amount of response *i*, the three panels of Figure 1 give three different answers. But, in addition, the same figure suggests a way around these complications.

For the specific examples of Figure 1, the analysis predicts unequivocally that the organism would seize any opportunity to select or produce a higher *C/I* ratio in preference to a lower one, however it might weight the two responses. Inspection of Figure 1 shows that if the schedule lines all pass beneath the basepoint, the line with the greatest slope, *C/I*, will always afford the smallest possible deviation from the basepoint levels of performance.

Collier, Hirsch, and Hamlin (1972) recently introduced a revealing variation of the conventional fixed-ratio schedule, a variation that allows the organism to control the size of each contingent reward. By allowing the organism to select any value of *C* it pleases, this novel procedure can show whether the organism ap-

proaches as closely as possible its basepoint levels of responding.

Marwine and Collier (1979, Experiment 1) tested four rats in daily 23-hr sessions on 12 schedules that each required some fixed number of lever presses (*I*) for each access to a water tube. Every lick at the tube activated a 5-min time delay circuit, and any 5-min pause in licking caused the tube to retract. The authors defined a drinking bout as drinking that continued for at least 30 sec, and ended with a pause of 5 min or more. Because the rat could vary the duration of each contingent bout by varying its rate of licking, it could also vary the volume consumed in the bout. Letting *C* represent ml/bout, we need only ask whether the rat typically produced a value of *C/I* that allowed it to approach as closely as possible its baseline levels of responding.

A reanalysis of the Marwine-Collier data shows that Rat R-1 could drink as much as 14.7 ml per bout, the average value achieved under a schedule that required 250 lever presses for each access to the tube. Its behavior under FR 250 shows that if tested under FR 1, the rat could achieve a *C/I* ratio as great as $14.7/1 = 14.7$ ml per lever press, or 2.9 ml under FR 5 ($14.7/5 = 2.9$). Figure 2 plots total volumetric intake against total lever presses, and displays

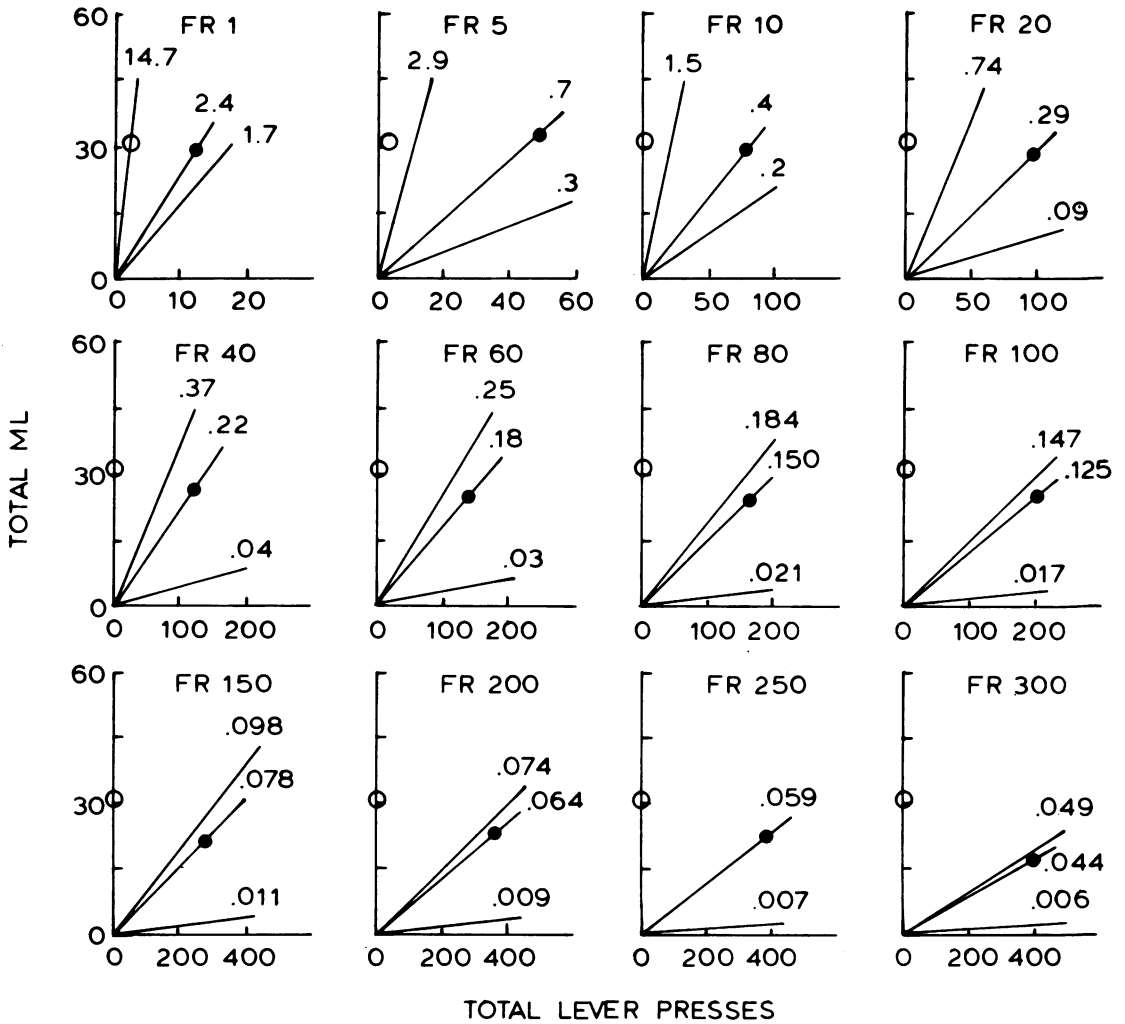


Fig. 2. Total water intake and total lever presses by Rat 1 under the baseline condition (unfilled circles) and twelve fixed-ratio schedules (filled circles) that allowed an optional amount of drinking per access to water. Based on Marwine and Collier (1979).

for Rat R-1 the greatest achievable ratio for each of the 12 schedules as the steepest line in each panel. The greatest ratio attainable is the slope of the steepest line, shown near the end of the line. The unfilled circles show volumetric intake under a baseline condition; baseline lever presses were not reported, but would surely have approached zero, as assumed in Figure 2. The filled circles show the rat's actual performance under the schedules; the *C/I* ratio actually attained appears near the end of the line that passes through the filled circle. Note that the ratios actually attained generally fell much below the highest ratios attainable. It follows that the rat generally failed to approach its baseline levels of responding as closely as it certainly could have done. Figures

3, 4, and 5 support the same conclusion for each of the three remaining rats. Averaged across schedules, the highest ratio attainable (1.96) differed significantly from the ratio observed (.42), $t(3) = 7.79, p < .01$.

Although the rats did not adapt to the schedules as well as they should have done in theory, they did not do as poorly as they might. The flattest lines in Figures 2, 3, 4, and 5 have slopes calculated by assuming that the rat would maintain under the schedule its baseline intake per bout. All of the ratios actually attained exceeded this ratio of total nonadaptation. Thus, the rats generally adjusted their behavior in the direction predicted by theory, but significantly less than predicted.

The same pattern emerged in a similar ex-

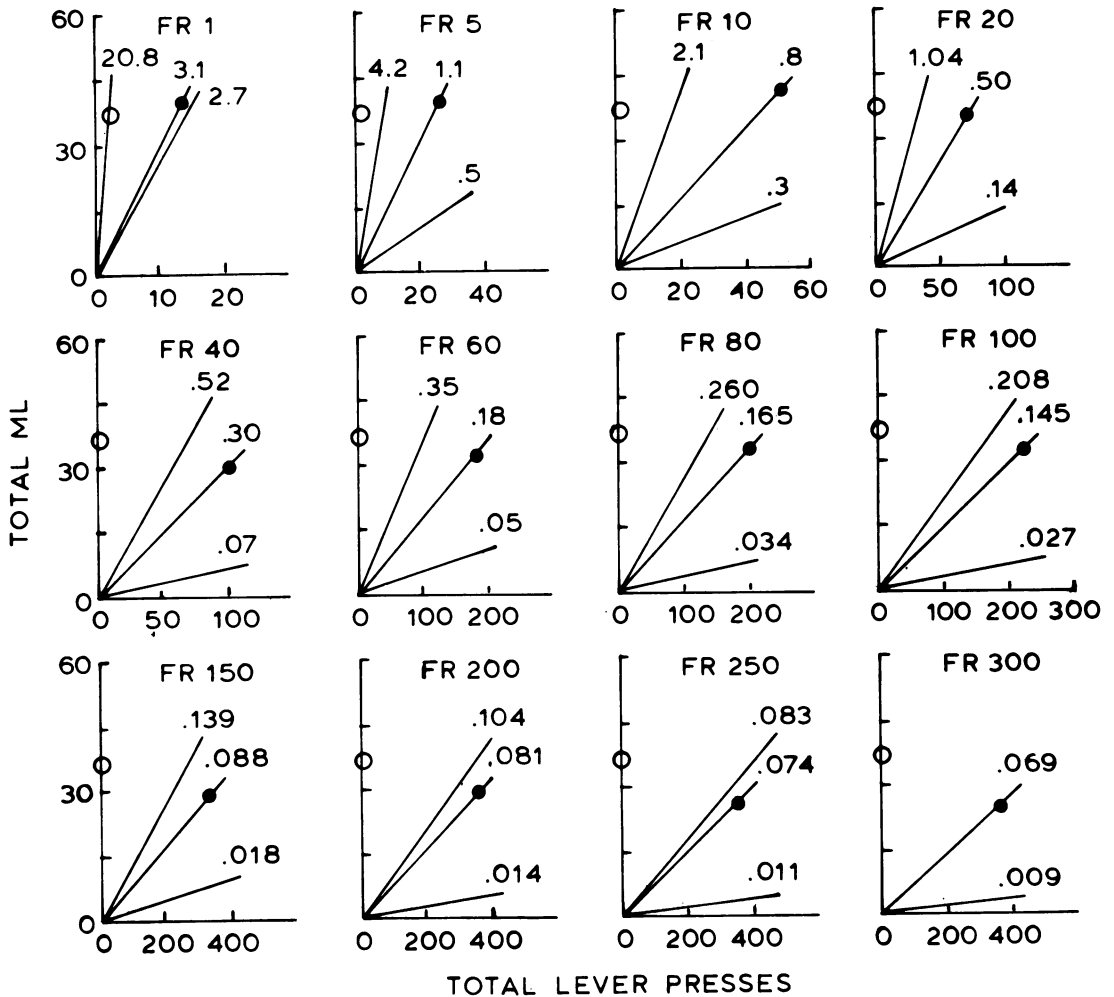


Fig. 3. Total water intake and total lever presses by Rat 2 under the baseline condition (unfilled circles) and twelve fixed-ratio schedules (filled circles) that allowed an optional amount of drinking per access to water. Based on Marwine and Collier (1979).

periment with three rats pressing a lever for food in 24-hr sessions, where the rat controlled the size of the contingent meal (Collier et al., 1972, Experiment 1). Figure 6 presents the re-analysis in the form of group means which reflect the behavior of individual rats.

These two sets of results suggest a simple generalization about the spacing of meals or drinking bouts. Letting m represent the least possible time between meals or bouts, m increases with I , the number of responses required for access to food or water. As m increased, the rats generally increased C , the size of the meal or the bout—a kind of adjustment consistent with the basepoint models, but appreciably smaller than predicted. Although the results suggest that the rat takes small meals

or drinks punctuated by short pauses, and large ones punctuated by long pauses, this characteristic spacing cannot explain the substantial deviation from the basepoints. The FR-1 schedule itself did nothing to prevent the rat from eating or drinking as much as it could, pausing a long time, and pressing the lever once more. Had it followed that pattern, the rat would have conformed to the basepoint models without giving up its characteristic spacing of large meals or drinks; in rejecting the opportunity to follow that pattern, the rat rejected the chance of a closer approach to the basepoint.

Statistical analysis of the group data showed the average size of the contingent drink or meal to be a power function of the required number of responses, $C = aI^b$. In the experiment on

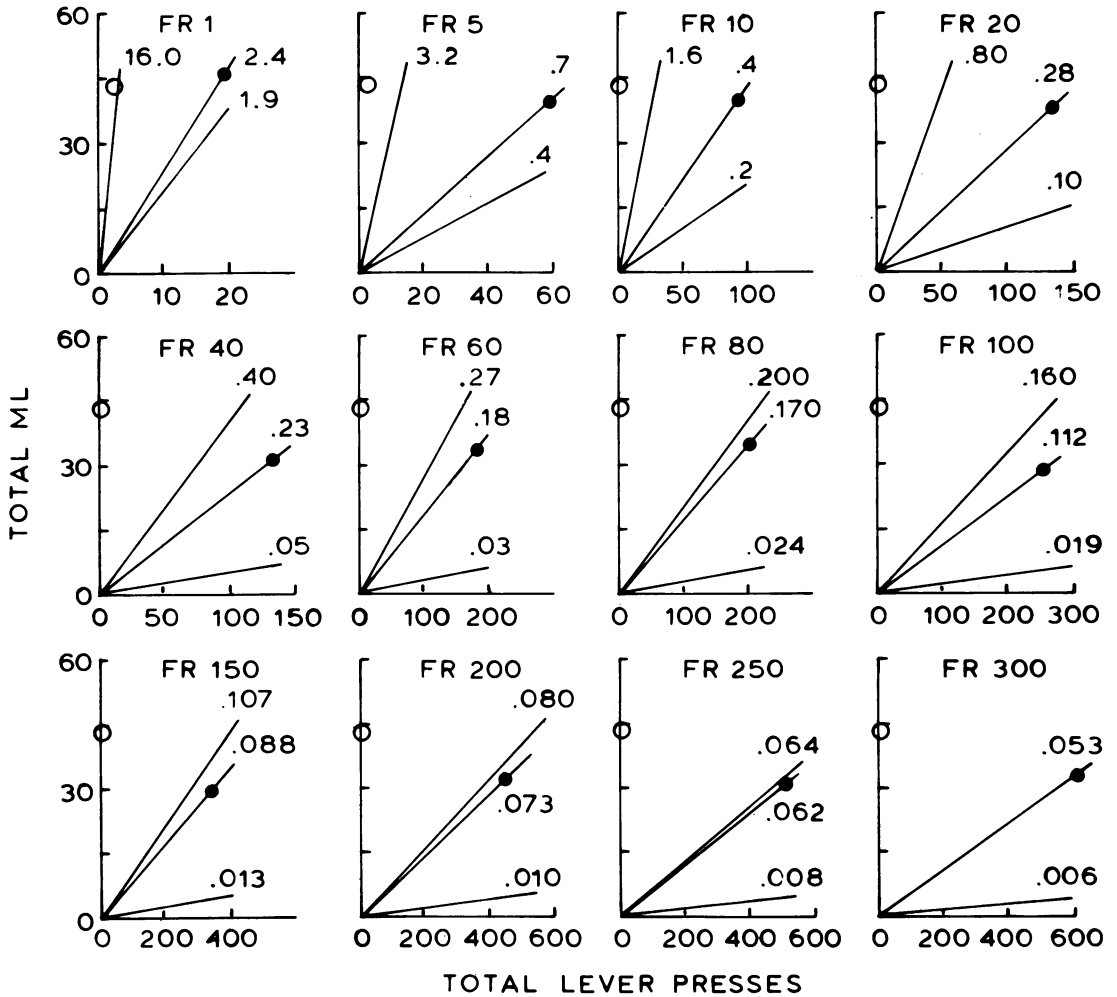


Fig. 4. Total water intake and total lever presses by Rat 3 under the baseline condition (unfilled circles) and twelve fixed-ratio schedules (filled circles) that allowed an optional amount of drinking per access to water. Based on Marwine and Collier (1979).

drinking, $ml = 2.39I^{.34}$, $r^2 = .99$; in the experiment on eating, $g = 1.82I^{.17}$, $r^2 = .96$. Because the slope is C/I , log slope varied linearly with $\log I$: From

$$C/I = aI^b/I,$$

$$\log C/I = \log a + b(\log I) - \log I$$

$$= \log a + (b - 1)\log I. \quad (1)$$

Because b was less than 1 in both experiments, log slope decreased linearly as $\log I$ increased (see Figure 7). The parallel lines in Figure 7 show the functions that would have occurred had the rats always selected the largest C observed (upper lines) or the C observed in baseline (lower lines). The figure reveals a steady convergence on the highest slopes attainable as the response requirement increased.

Collier's procedure shows that rats offered a simple ratio schedule with an optional magnitude of contingent food or water reward do not select a C/I ratio that puts them as close as possible to the baseline levels of responding. Additional experiments with conventional concurrent ratio schedules reveal the same phenomenon in a slightly different way. In the conventional concurrent schedule with ratio Components 1 and 2, the experimenter fixes C_1/I_1 and C_2/I_2 , but the organism may vary the overall reward/response ratio by varying the number of times it completes each component. If it responds exclusively on one component or the other, the slope of the function will be C_1/I_1 or C_2/I_2 . More generally, the slope will be $(N_1C_1 + N_2C_2)/(N_1I_1 + N_2I_2)$, where

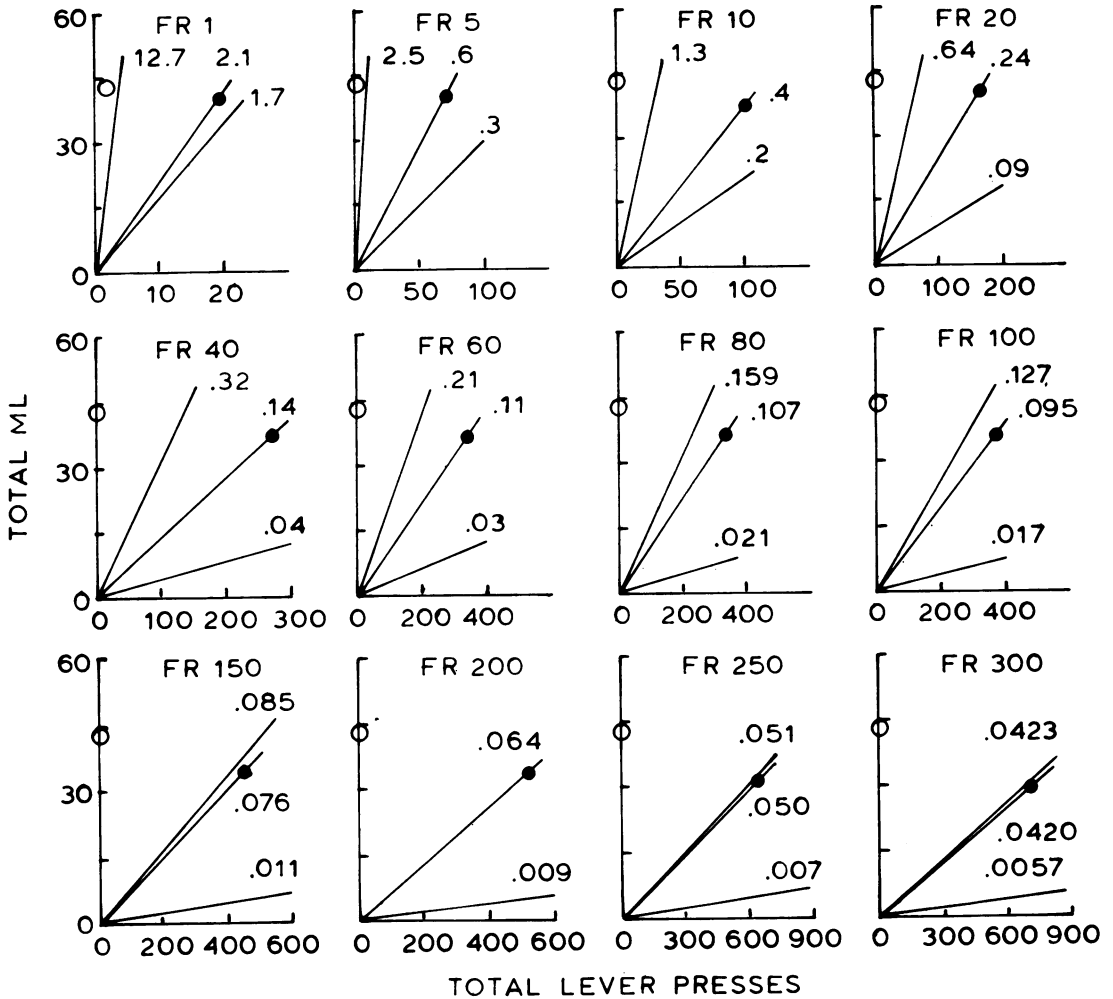


Fig. 5. Total water intake and total lever presses by Rat 4 under the baseline condition (unfilled circles) and twelve fixed-ratio schedules (filled circles) that allowed an optional amount of drinking per access to water. Based on Marwine and Collier (1979).

N refers to the number of times the organism completes a particular component. If the organism samples both components the slope will fall somewhere between the two possible extremes, C_1/I_1 and C_2/I_2 .

In a recent example, Lea and Roper (1977, Series 3) tested six rats on four concurrent fixed-ratio schedules in 1-hr sessions. Figure 8 shows the reanalysis of their data, plotting the total number of 45-mg food pellets consumed against the total number of lever presses. Base-points were not reported, but would have fallen near the upper left-hand corner of each panel (Lea, Note 1). Each of the six rats sampled both components under all four schedules, and thereby failed to approach the baseline

levels of responding as closely as they might have done. In each of the four panels, the line with intermediate slope represents the mean slope observed for the group. Binomial tests show that the slope observed fell significantly below the highest slope attainable under each of the four schedules ($p = .03$, two-tailed).

Figure 9 presents a similar analysis of lever pressing and water licking in four rats tested in 1-hr sessions (Shapiro & Allison, 1978). Each unfilled symbol shows total presses and total licks for an individual rat recorded in the paired baseline condition. Each filled symbol shows the response totals recorded under one of four concurrent fixed-ratio schedules (60 licks for 2 or 8 presses, 120 or 30 for 2, 60 or 30

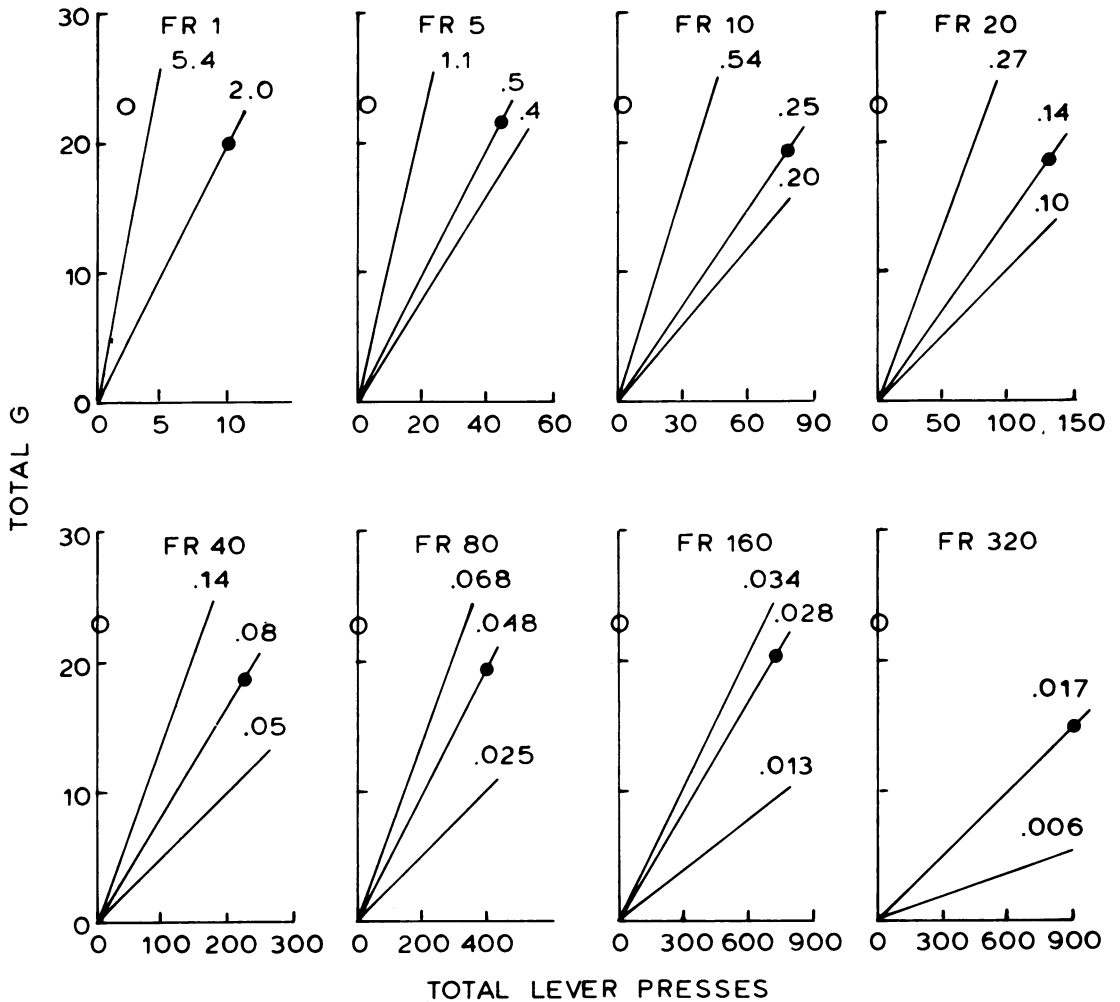


Fig. 6. Total food intake and total lever presses under the baseline condition (unfilled circles) and eight fixed-ratio schedules (filled circles) that allowed an optional amount of eating per access to food. Group means for three rats, based on Collier et al. (1972).

for 2, and 60 for 2 or 4). None of the rats approached the highest slope attainable; averaged across schedules, the slope observed (22.1) fell significantly below the highest attainable (40.0), $t(3) = 4.16, p < .05$, two-tailed.

All of the studies reviewed thus far exemplify the controlled-time paradigm (Allison, in press; Allison & Timberlake, 1975), where all experimental sessions have the same duration. We can use the same technique in analyzing experiments in the controlled-amount paradigm, where all sessions end after a fixed amount of contingent reward. An experiment by Herrnstein and Loveland (1975) on concurrent variable-ratio schedules illustrates the controlled-amount paradigm, as each session ended after the pigeon had received 60 peck-contin-

gent accesses to grain. Each access lasted 3 sec in Series 1 ($C = 3$), and 2 sec in Series 2 and 3 ($C = 2$). The first two series used a changeover delay, and the third did not. Although the authors reported only the proportion of pecks on the left-hand key, the response totals needed to calculate the slope of the response function can be calculated with the help of an equation,

$$N_L I_L / (N_L I_L + N_R I_R) = p. \quad (2)$$

The subscripts in Equation 2 stand for the left- and right-hand keys, N signifies the number of contingent accesses to grain, I the variable-ratio response requirement, and p the proportion of left-key responses. The number of accesses gained by pecking the left-hand key can

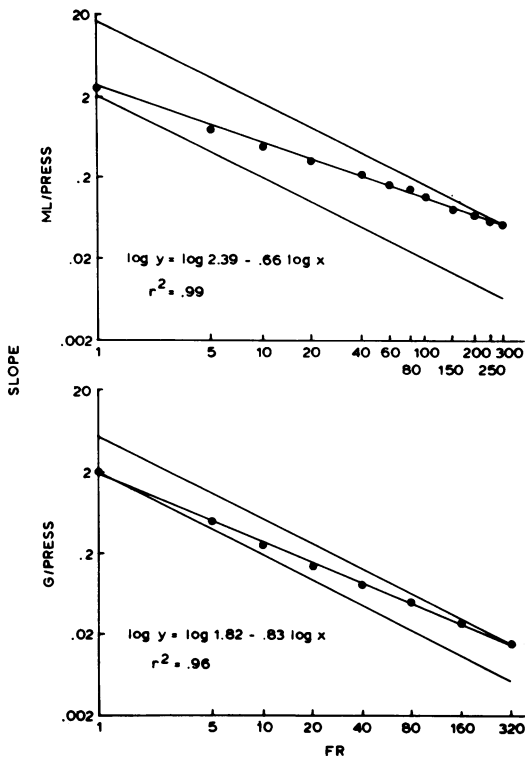


Fig. 7. Slope as a function of the FR lever press requirement in log coordinates. Slope refers to ml/press in the upper panel, based on Marwine and Collier (1979), and g/press in the lower panel, based on Collier et al. (1972). Parallel lines show the slopes that would have occurred had the rats always selected the largest bout or meal observed (upper lines) or the size observed in baseline (lower lines).

be calculated by substituting for N_R the expression $N_R = 60 - N_L$, yielding

$$N_L = pI_R 60 / (I_L - pI_L + pI_R). \quad (3)$$

Having solved for N_L and N_R , the slope of the response function comes to $180 / (N_L I_L + N_R I_R)$ for Series 1, which allowed a total of $(60)(3) = 180$ sec of access to grain in each session. For Series 2 and 3, which allowed 60 2-sec accesses, the numerator would be 120.

Group means for the five pigeons appear in Figure 10. The basepoints shown in the figure assume that in a paired baseline session the pigeon would peck the key relatively little in eating free grain for 180 or 120 sec. Of the nine panels in Figure 10, the three toward the upper right-hand corner show results that conform to theory. In each of these three, all five pigeons responded exclusively on the component nearest the basepoint. But most of the panels sug-

gest that the pigeons did not respond exclusively on either component. In four of the panels, no pigeon responded exclusively on the component with the steeper slope (Series 1, VR 25 VR 35; Series 2, VR 50 VR 70; Series 3, VR 40 VR 80, and VR 50 VR 70).

Ironically, the Herrnstein-Loveland study was offered and is often cited as a demonstration of maximizing, i.e., exclusive responding on the ratio component that offers the highest rate of reinforcement. The present analysis shows that the results demonstrated no such thing. Averaged across schedules and series, the pigeons actually showed a statistically significant departure from exclusive responding; the average slope expected on the maximization hypothesis (.116) was slightly but significantly greater than the average slope observed (.113), $t(4) = 4.13$, $p < .02$, two-tailed. Thus, the Herrnstein-Loveland results join all of the others presented in this paper in showing that the organism does not necessarily select or produce the C/I ratio that would tend to reproduce the baseline levels of responding. If we view the contingent reward as a reinforcer, each such failure demonstrates in addition a failure to maximize the rate of reinforcement.

The departure from maximization in the three experiments on concurrent ratio schedules cannot be dismissed as an inevitable need to sample both components. Like Herrnstein and Loveland (1975), Lea and Roper (1977) kept each component in the same location across sessions, minimizing the need to discover anew the location of the richer component. Shapiro and Allison (1978) varied the location of each component from session to session, but showed that a liberal allowance for initial sampling still revealed a substantial departure from exclusive responding on the richer component. Casual observations in the latter experiment suggested that a formal record of the behavior would have revealed a large amount of sampling toward the end of the session, showing that the rat does not confine its sampling to an initial warmup period.

We can fit the results of all three experiments by supposing that the relative number of times the organism selects a component is a power function of the relative potential immediacy of reward (Duncan & Fantino, 1972; Shapiro & Allison, 1978). Because I_L and I_R represent the number of responses required by the two components, the potential immediacy of

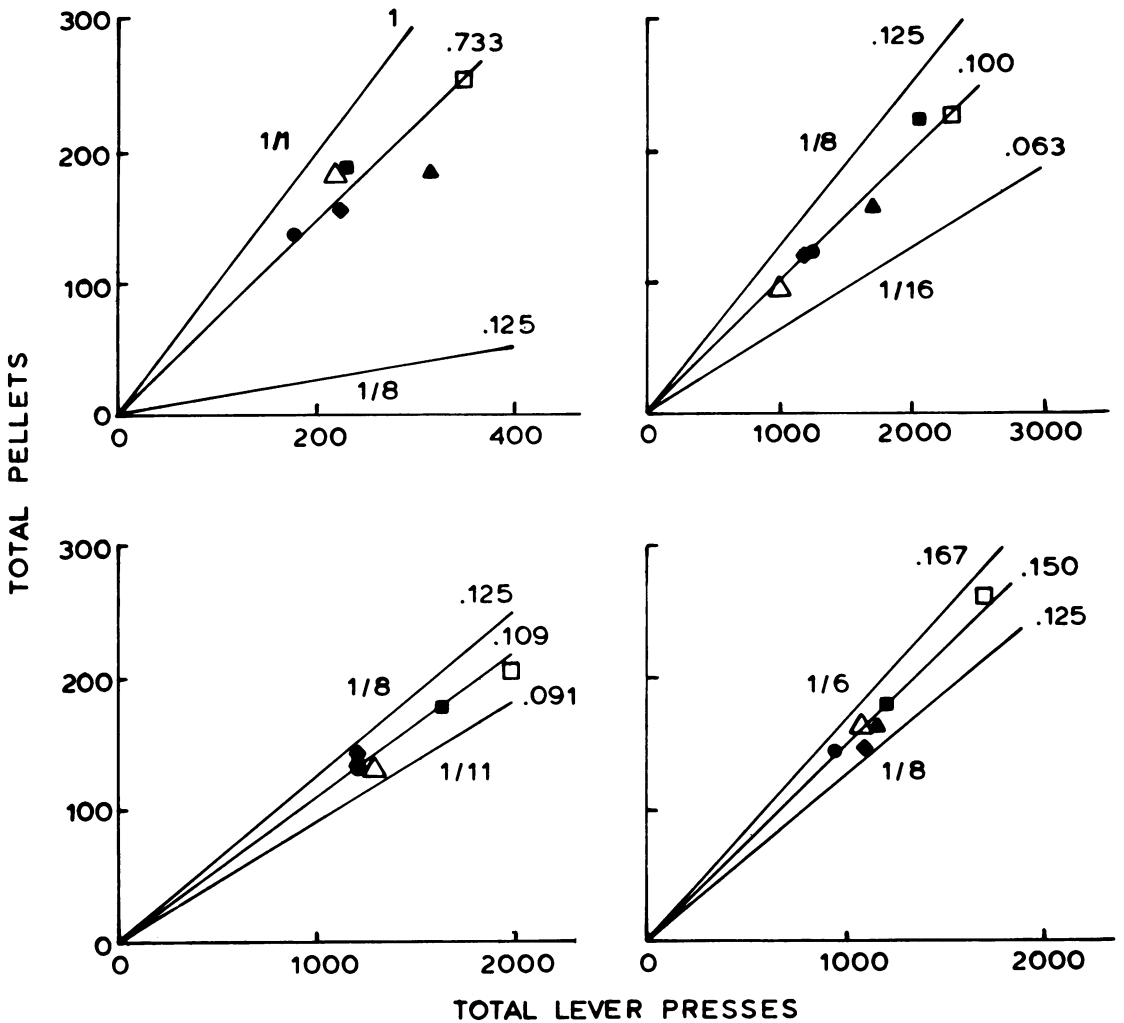


Fig. 8. Total 45-mg food pellets and total lever presses by six rats tested under four concurrent fixed-ratio schedules allowing one pellet for 1, 6, 8, 11, or 16 lever presses. Based on Lea and Roper (1977).

reward is $1/I_1$ or $1/I_2$. Potential immediacy of reward in Component 1, relative to Component 2, is then $(1/I_1)/(1/I_2) = I_2/I_1$. According to the hypothesis,

$$N_1/N_2 = a(I_2/I_1)^b \quad (4)$$

The constant b reflects the organism's sensitivity to any difference between I_2 and I_1 . The constant a reflects the amount of bias attributable to variables other than I_2/I_1 , such as the location of the component. In the absence of bias, $a = 1$.

We wish to calculate the slope predicted by Equation 4, where

$$\text{Slope} = (N_1C_1 + N_2C_2)/(N_1I_1 + N_2I_2) \quad (5)$$

Solving Equation 4 for N_1 , substituting the re-

sult into Equation 5, and cancelling N_2 , we arrive at

$$\text{Slope} = [a(I_2/I_1)^b C_1 + C_2]/[a(I_2/I_1)^b I_1 + I_2] \quad (6)$$

as the slope predicted by Equation 4.

The least squares estimates of a and b were 1.24 and 1.26 in the data from Lea and Roper (1977), .84 and .83 in the data from Shapiro and Allison (1978), and .40 and 4.53 in the data from Herrnstein and Loveland (1975). Note that the bias constant a came closer to 1 in the experiment that balanced the location of the component within subjects (Shapiro & Allison, 1978) than in the experiments that confounded the two variables.

Having calculated the slopes predicted by Equation 6, we can compare the three experi-

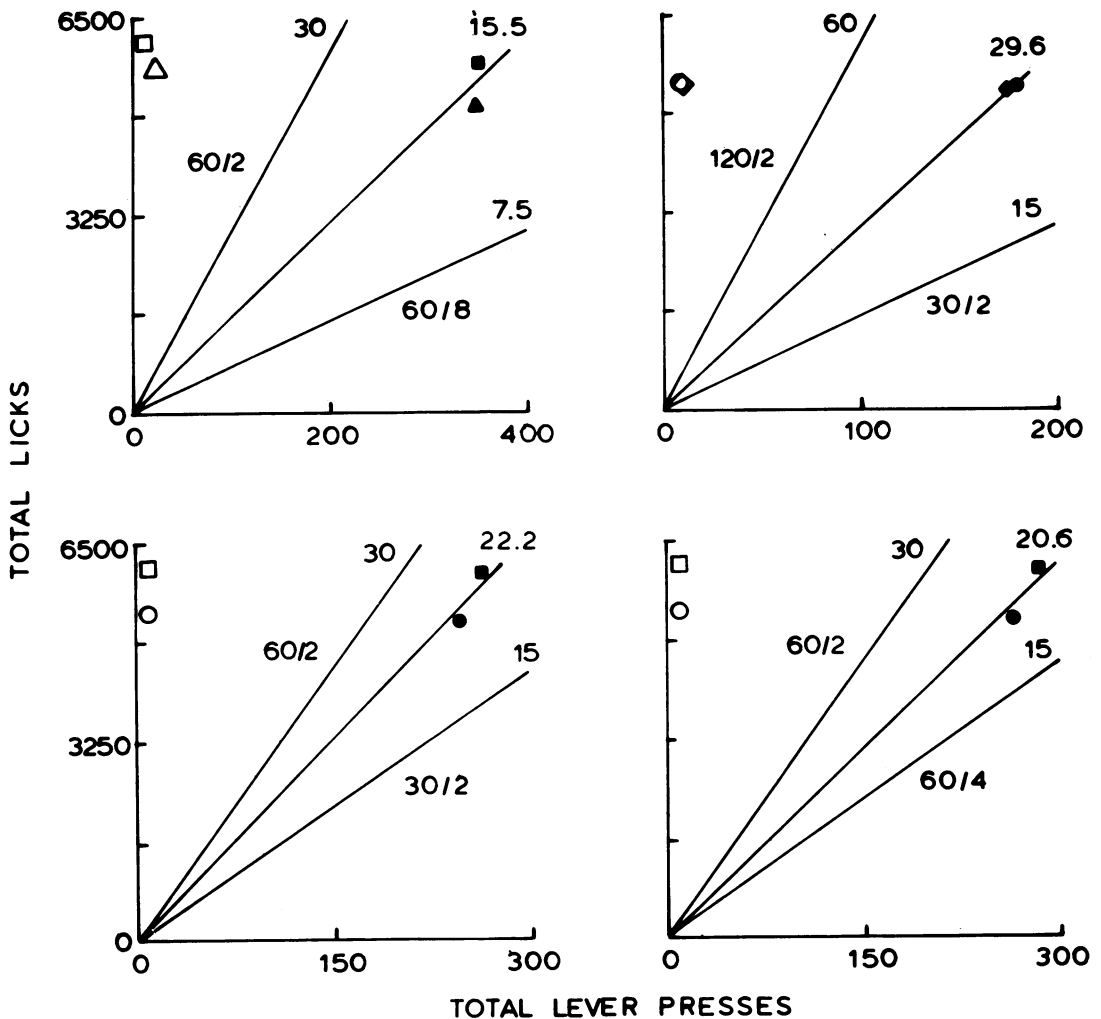


Fig. 9. Total water licks and total lever presses by four rats under the baseline condition (unfilled symbols) and four concurrent fixed-ratio schedules (filled symbols) allowing 30, 60, or 120 licks for 2, 4, or 8 lever presses. Based on Shapiro and Allison (1978).

ments on a common scale by dividing the slope observed or predicted by the maximum slope attainable, slope/slope max. Exclusive responding on the richer component is indicated if slope/slope max = 1, and values less than 1 indicate a departure from exclusive responding.

The bulk of the 17 observed values in Figure 11 fall short of 1, indicating a general departure from exclusive responding on the richer alternative. The conclusion draws some of its importance from a number of recent theories that predict maximization on concurrent ratio schedules (Myerson & Miezin, 1980; Rachlin & Burkhard, 1978; Rachlin, Kagel, & Battalio, 1980). The results shown in Figure 11 suggest that we should construe the prediction of

maximization as a measure of failure, not success.

Figure 11 reveals close agreement between values observed (y) and values predicted (x) for slope/slope max, $y = -.06 + 1.08x$, $r^2 = .96$. The model did somewhat better in accounting for two sets of results than the third, but different experiments gave similar observed values for similar predicted values. The overall fit provided by Equation 4 appears reasonably good in view of the large number of methodological differences among the three experiments: rat vs. pigeon, FR vs. VR, key peck vs. lever press, eat vs. drink, and controlled-time vs. controlled-amount.

In summary, theories which predict instrumental performance under schedule constraint

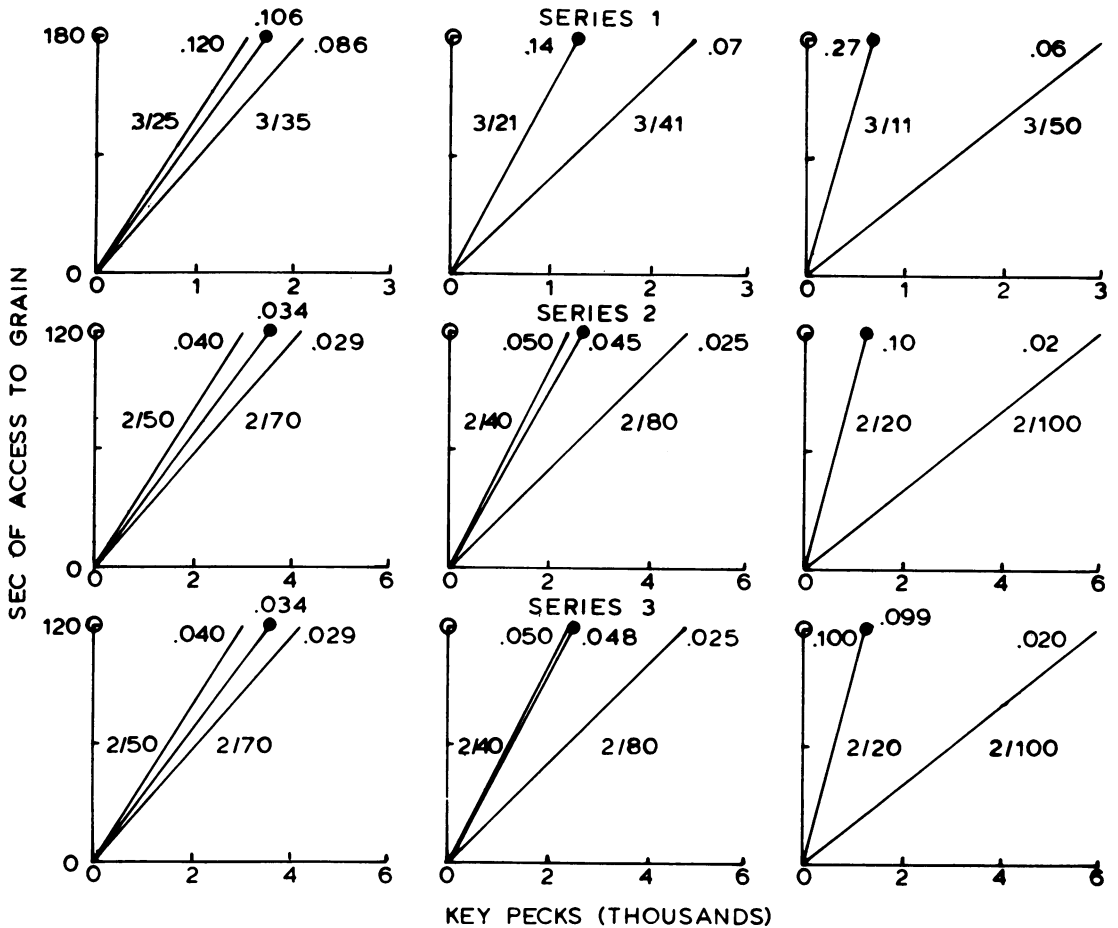


Fig. 10. Total sec of access to grain and total key pecks under the baseline condition (unfilled circles) and six concurrent variable-ratio schedules. Group means for five pigeons. Series 1 allowed 60 3-sec accesses for 11, 21, 25, 35, 41, or 50 pecks per access. Series 2 and 3 allowed 60 2-sec accesses for 20, 40, 50, 70, 80, or 100 pecks per access. Series 1 and 2 used a changeover delay, Series 3 did not. Based on Herrnstein and Loveland (1975).

by assuming that the basepoint represents a behavioral ideal may generate the right predictions for the wrong reason. Too often the basic assumption fails a more direct test; too often the organism rejects the chance of a closer approach to the basepoint. In the experiments reviewed here, by failing to approach the basepoint more closely the organism secured less than the maximum rate of reinforcement, and thereby contradicted a related class of theories which assume or predict maximization.

REFERENCE NOTE

1. Lea, S. E. G. Personal communication, June 9, 1979.

REFERENCES

Allison, J. Constraints on performance in two elementary paradigms. In M. L. Commons, R. Herrnstein,

& H. Rachlin (Eds.), *Harvard symposium on quantitative analysis of operant behavior* (Vol. 2): *Matching and maximizing*. Elmsford, New York: Pergamon, in press.

Allison, J., & Timberlake, W. Response deprivation and instrumental performance in the controlled-amount paradigm. *Learning and Motivation*, 1975, 6, 122-142.

Collier, G. H., Hirsch, E., & Hamlin, P. H. The ecological determinants of reinforcement in the rat. *Physiology and Behavior*, 1972, 9, 705-716.

Duncan, B., & Fantino, E. The psychological distance to reward. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 23-24.

Herrnstein, R. J., & Loveland, D. H. Maximizing and matching on concurrent ratio schedules. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 107-116.

Heth, C. D., & Warren, A. G. Response deprivation and response satiation as determinants of instrumental performance: Some data and theory. *Animal Learning and Behavior*, 1978, 6, 294-300.

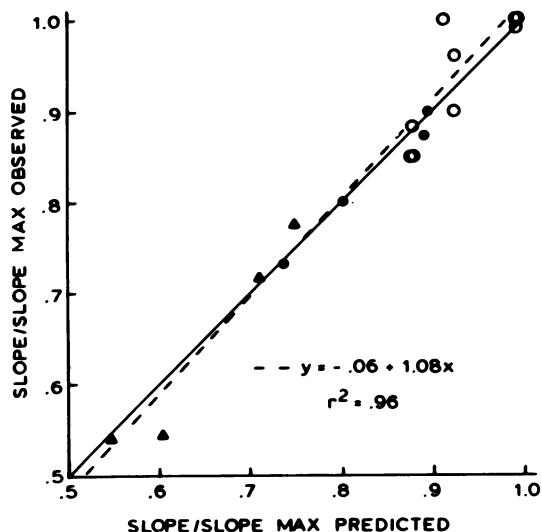


Fig. 11. Observed and predicted values of slope/slope max. Based on Lea and Roper (1977; filled circles), Shapiro and Allison (1978; filled triangles), and Herrnstein and Loveland (1975; unfilled circles). Values of 1 indicate exclusive responding on the richer component of the concurrent ratio schedule.

Lea, S. E. G., & Roper, T. J. Demand for food in fixed-ratio schedules as a function of the quality of concurrently available reinforcement. *Journal of the Experimental Analysis of Behavior*, 1977, 27, 371-380.

Marwine, A., & Collier, G. The rat at the waterhole. *Journal of Comparative and Physiological Psychology*, 1979, 93, 391-402.

Mazur, J. E. The matching law and quantifications related to Premack's principle. *Journal of Experimental Psychology: Animal Behavior Processes*, 1975, 1, 374-386.

Myerson, J., & Miezin, F. M. The kinetics of choice: An operant systems analysis. *Psychological Review*, 1980, 87, 160-174.

Rachlin, H., & Burkhard, B. The temporal triangle: Response substitution in instrumental conditioning. *Psychological Review*, 1978, 85, 22-47.

Rachlin, H., Kagel, J. H., & Battalio, R. C. Substitutability in time allocation. *Psychological Review*, 1980, 87, 355-374.

Shapiro, N., & Allison, J. Conservation, choice, and the concurrent fixed-ratio schedule. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 211-223.

Staddon, J. E. R. Operant behavior as adaptation to constraint. *Journal of Experimental Psychology: General*, 1979, 108, 48-67.

Timberlake, W. A molar equilibrium theory of learned performance. In G. Bower (Ed.), *The psychology of learning and motivation* (Vol. 14). New York: Academic Press, 1980.

Timberlake, W., & Allison, J. Response deprivation: An empirical approach to instrumental performance. *Psychological Review*, 1974, 81, 146-164.

Received August 11, 1980

Final acceptance January 19, 1981