

THE APPLICATION OF THE MATCHING LAW TO SIMPLE RATIO SCHEDULES

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To account for performance under simple ratio schedules, Pear (1975) derived the following equation from the matching law (Herrnstein, 1970):

$$P = k - nR_o \quad (1)$$

where P is number of responses, k is a constant, n is the average number of responses required for one reinforcement, and R_o is the reinforcement for other alternatives.² This paper considers briefly the empirical adequacy of this equation in predicting responding under ratio schedules.

Equation 1 predicts two effects of questionable generality: (a) responding should decrease as the average value of the ratio increases until (b) at some value of the ratio, responding goes to zero. The prediction of an inverse relation between number of responses and ratio size appears contradicted by considerable data. In fixed-ratio (FR) schedules the most common finding is a direct relation between number of responses and ratio size for low to moderate ratio values. For example, between FR 1 and FR 20, increased ratio requirement for a food reward is accompanied by increased key pecking in pigeons (Ferster and Skinner, 1957; Findley, 1962), and manipulation responses in rats (Barofsky and Hurwitz, 1968; Boren, 1961; Collier, Hirsch and Hamlin, 1972; Teitelbaum, 1957), gerbils (Vanderweele, Abelson, and Tello, 1973), guinea pigs (Hirsch and Collier, 1974), goldfish (Rozin and Mayer, 1964), monkeys (Findley, 1959; Hamilton and Brobeck, 1964), and humans (Hutchinson and Azrin, 1961). A further increase in ratio size often produces a decline in number of responses.

Increases in the size of variable- and random-ratio schedules appear to produce changes similar to those that occur in the fixed-ratio case, though the relation is not always as marked (e.g., Brandauer, 1958; Kelly, 1974; Priddle-Higson, Lowe, and Harzem, 1976). Performance on these latter schedules may be affected by

the order in which ratios are imposed and whether different groups of subjects are run at each ratio (Sidley and Schoenfeld, 1964).

Several investigators have argued that overall rate is not an appropriate measure of responding because it is partly based on time during which the animal is engaged in behavior other than the instrumental response. The most extreme form of this argument holds that the best measure of performance is the running rate calculated on a time base obtained by subtracting reward time and postreinforcement pause (PRP) from total session time. Using this measure, Powell (1968) found an inverse relation between rate of key pecking and fixed-ratio size for two of three birds, though the birds showed several reversals of this trend. Priddle-Higson *et al.* (1976) found an inverse relation between the rate at which rats bar pressed for milk and the size of the variable ratio. However, Farmer and Schoenfeld (1967) found no relation or perhaps a slight positive trend relating key pecking and ratio value in random ratios. Also, Kelly (1974) found a positive relation between panel pressing for water in monkeys and size of the random ratio.

All measures of responding are arbitrary to an extent, deriving their justification from an underlying rationale and their ability to fit data to the rationale. In the case of Equation 1, it is not clear that there exists a generally appropriate combination of rationale and data. The strongest justification for the use of running rate is that, of all rate measures, it comes closest to showing a direct relation between responding and frequency of reward (Priddle-Higson *et al.*, 1976). Neither this rationale nor the fit to data reviewed above appears to preclude the active consideration of rate measures other than the running rate.

The second prediction, that responding should fall to zero with increases in the ratio value, is supported by data on key pecking in pigeons (e.g., Ferster and Skinner, 1957). However, the accuracy of this prediction may be limited to the case of responses with an operant level near zero. In the case of responses with a higher operant level, it seems most reasonable that responding should return to the operant level, rather than zero, as the ratio increases. In a recent test of this supposition, I trained six albino rats to lick water on a fixed-ratio schedule to obtain 10 sec of access to a 0.1% saccharin solution. The operant level of licking was well above zero for all rats. As the ratio value was increased from five to 145 licks, each rat first increased water licking, then gradually decreased water licking to approximately its operant level.

It might be possible to modify Equation 1 to deal with responses of relatively high operant baseline by

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²Equation (1) is interpretable only if R_o , P , and $k \geq 0$, and $n > 0$. A plausible interpretation of $n = 0$ is that no schedule is in effect and the reinforcer is continuously and freely available to the subject. However, this value of n creates problems in the derivation of Equation 1, as well as leading to the counter-intuitive prediction that maximum rate should occur in a paired free-operant baseline.

subtracting the baseline of the response from the left side of the equation. However, this procedure will not account for interactions between the operant level of a response and its rate under a schedule. Several investigators have shown that the increase in responding under a fixed-ratio schedule is related to the operant level of the instrumental response (Bauermeister, 1975; Schaeffer, 1965; Timberlake and Allison, 1974).

Equation 1 also suffers from an inability to predict the results of changes in the amount of reward. In Pear's derivation of Equation 1, it was necessary to restrict R (the amount or frequency of reward in Herrnstein's, 1970, equation) to refer only to the frequency of reward. Thus, the effect of changes in amount of reward cannot be considered using Equation 1. That amount of reward is an important determinant of ratio performance can be seen in several experiments using different species and responses. For example, Pickens and Thompson (1968) using rats, Pickens, Bloom, and Thompson (1969) using monkeys, and Rozin and Mayer (1961) using goldfish showed that number of manipulation responses was inversely related to amount of food reward. Similar results were shown with rats licking water for access to a running wheel (Premack, Schaeffer, and Hundt, 1964), wheel running for access to water (Klajner, 1975), and bar pressing for access to heat (Weiss and Laties, 1960), cocaine (Pickens and Thompson, 1968), and morphine (Weeks and Collins, 1964).

In sum, the status of Equation 1 as a predictor of performance on simple ratio schedules is unclear. Some of its empirical shortcomings might be met by allowing R_n of k to vary as a function of amount of reward, ratio value, or operant baseline. Whatever the results of such a procedure, it seems that the prediction of performance on simple ratio schedules is more complex than indicated by Equation 1. It appears that future research on simple ratio schedules should consider the effects of manipulating amount of reward, the operant level of the instrumental response, and the type of simple ratio schedule employed. Further, attention should be directed to the results of and rationale for using alternative measures of response rate.

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