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LOCAL RATES OF RESPONDING AND REINFORCEMENT DURING CONCURRENT SCHEDULES

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The literature was searched for information about the local rates of responding and reinforcement during concurrent schedules. The local rates of reinforcement obtained from the two components of a concurrent schedule were equal when a long-duration changeover delay was used and when many sessions were conducted, except when the two components provided different simple schedules. The local rates of responding were equal under some conditions, but they differed when one component provided a ratio and the other an interval schedule. Across schedules, local rates of reinforcement changed with changes in the schedule of reinforcement. Local rates of responding did not change with changes in changeover-delay duration but did with changes in the changeover ratio and with changes in the programmed rates of reinforcement. The results generally conform to the Equalizing and Melioration Principles and help to clarify current statements of the Matching Law. The results also suggest that changes in the local rates of responding and reinforcement may be orderly across schedules.

Key words: local rates of responding, local rates of reinforcement, equalizing, melioration, undermatching, bias, concurrent schedules

Many theories have been proposed to describe concurrent schedule performance (e.g., Baum, 1974; Herrnstein, 1970). Most of these theories, and the reviews of the literature directed at them, have examined the overall rates of responding and reinforcement while neglecting the local rates. The overall rates of responding and reinforcement are the number of responses (P_1 or P_2) emitted during, or the number of reinforcers (R_1 or R_2) obtained from, Components 1 or 2, divided by the total session time (T). The local rates of responding and reinforcement are the number of responses (P_1 or P_2) emitted during, or the number of reinforcers obtained from (R_1 or R_2), Components 1 or 2, divided by the time spent responding on that component (T_1 or T_2).

Local rates have been neglected even though three theories have been proposed to describe them. First, Rachlin (1973) has argued that the local rates of responding emitted during concurrent schedules will remain constant and equal to each other in spite of changes in the overall rate of reinforcement provided by either component. Second, Killeen (1972) and Rachlin (1973) have proposed the Equalizing Principle, which argues that subjects adjust the time they spend responding on each component of a concurrent schedule so that the local rates of reinforcement obtained from the components are equal. Third, Herrnstein and Vaughan (1980) have proposed a molecular version of the Equalizing Principle called Melioration. During Melioration, subjects shift to the component of the concurrent schedule that provides the momentarily higher rate of reinforcement. As a result, overall behavior equates the local rates of reinforcement obtained from the components, as described by the Equalizing Principle.

Local rates of responding and reinforcement should be studied because they can provide information bearing on these three generalizations about behavior. No studies have directly examined how well Equalizing, Melioration, and the proposed equality of response rates actually describe the concurrent schedule literature.

Local rates of responding and reinforcement should also be studied because they may provide information about other theories that have been proposed to describe the absolute and relative rates of responding during concur-

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rent schedules. Absolute response rates are the number of responses emitted per time period during the components of concurrent schedules. They are overall rates if calculated using total session time (P_1/T). They are local rates if calculated using the time spent responding on that component (P_1/T_1). Relative rates are the number of responses emitted during one component of a concurrent schedule divided by the number emitted during the other (P_1/P_2).

Little is known about the factors that govern the absolute rates of responding during concurrent schedules. At present, the most prominent theory of absolute response rates (Herrnstein, 1970) appears to be inadequate (McSweeney, Melville, & Whipple, in press). Therefore, studying local response rates might provide needed information about absolute response rates during concurrent schedules. If changes in local response rates were orderly, studying them might eventually provide information that would form the basis for future theories of absolute response rates.

Studying local rates of responding and reinforcement can also provide information about the Matching Law, the most prominent theory of relative response rates. A modified version of the Matching Law, as stated by Herrnstein (1970), appears in Equation 1,

$$\frac{P_1}{P_2}=\frac{R_1}{R_2}. \qquad (1)$$

The Generalized Matching Law, formulated by Baum (1974), appears in Equation 2,

$$\frac{P_1}{P_2}=\frac{T_1}{T_2}=b\left(\frac{R_1}{R_2}\right)^a . \qquad (2)$$

a and b are parameters, which are called undermatching and bias, respectively. The Matching Laws are particularly important because a large number of data conform closely to them (e.g., Baum, 1979; Wearden & Burgess, 1982).

Studying the local rates of responding and reinforcement can provide information about the Matching Laws in three ways. First, studying the local rates of responding can test Baum's (1974) assumption that the relative rates of responding and the relative time spent responding on a component are equivalent measures of behavior (see Equation 2). Recently, studies have suggested that these measures may not be equal because the a and b parameters for Equation 2 sometimes differ for the two measures (e.g., Baum, 1979). However, these studies have not determined whether these differences are statistically significant (cf. Mullins, Agunwamba, & Donohoe, 1982). As a result, the circumstances that produce significant differences in the parameters, and therefore differences between the measures, are not known. Studying the local rates of responding can provide information about this topic because the two measures must be equal (i.e., $P_1/P_2 = T_1/T_2$) whenever the local rates of responding are equal (i.e., $P_1/T_1 = P_2/T_2$). Statistically significant differences between local response rates imply that the two measures of behavior are also different.

Second, studying the local rates of reinforcement can determine whether the Equalizing and Melioration Principles or Equation 2 are better descriptions of the relative time spent responding on the components of concurrent schedules. The major difference between the Principles and Equation 2 is the value of the a and b parameters for the relative time spent measure of behavior. If Equalizing and Melioration are correct, then $R_1/T_1 = R_2/T_2$. This will conform to Equation 3, an implication of Equation 2 when a and b equal 1.0. If Equation 2 is correct, then the a and b parameters need not equal 1.0. Thus,

$$\frac{R_2{}^a}{T_2}=b\left(\frac{R_1{}^a}{T_1}\right). \qquad (3)$$

Determining whether a and b differ significantly from 1.0 has been difficult when the data are examined according to Equation 2. The observed values of a are frequently less than 1.0 when the relative time spent responding on a component is plotted as a function of the relative rate of reinforcement obtained from that component (e.g., Myers & Myers, 1977). But again it has been difficult to determine whether the values of this parameter are statistically significantly different from 1.0. Baum (1979) reviewed the literature and found little evidence that the exponent of Equation 2 differs from 1.0 when the relative time spent is the measure of behavior. Mullins et al. (1982) reviewed the same literature, using a different statistical test, and concluded that the exponent was less than 1.0.

Studying the Equalizing Principle can provide an additional test of whether and when a and b differ significantly from 1.0. Equation

3 shows that the data will violate the Equalizing Principle if either a or b or both differ significantly from 1.0. The data will conform to the Equalizing Principle if a and b equal 1.0. A detailed description of when a and b equal 1.0 can be obtained by a careful examination of when the data do and do not conform to the Equalizing Principle.

Finally, studying both the local rates of responding and the local rates of reinforcement can help to determine whether Equation 1 or Equation 2 provides a better description of the relative rates of responding during concurrent schedules. These equations differ only over whether the a and b parameters are significantly different from 1.0. Again, the observed a parameters are frequently less than 1.0 when the relative rates of responding are plotted as a function of the relative rates of reinforcement (e.g., Baum, 1979). However, the question of whether and when these parameters differ significantly from 1.0 has not been answered (cf. Mullins et al., 1982). Studying the local rates of responding and reinforcement can help to answer this question because data will conform to Equation 1 whenever both the local rates of responding and reinforcement are equal between the components, because $P_1/T_1 = P_2/T_2$ and $R_1/T_1 = R_2/T_2$ implies that $P_1/P_2 = R_1/R_2$. Violations of the equality of the local rates of responding or the local rates of reinforcement or both will indicate that the data violate Equation 1.

The present paper reviews the literature about the local rates of responding and reinforcement. It tests the Equalizing and Melioration Principles and the proposed equality of response rates. It examines changes in the local rates of responding and reinforcement across as well as within concurrent schedules. Although Equalizing, Melioration, and the equality of response rates describe rates of responding and reinforcement within concurrent schedules, changes across schedules will also be examined to identify consistent relations in the data.

TREATMENT OF THE DATA

The literature was searched for concurrent schedule studies that included enough information to calculate local rates. Studies were eliminated if they did not use standard concurrent procedures (e.g., if reinforcers were provided by a concurrent-chain procedure or if reinforcers were signaled). Studies were also eliminated if they provided negative reinforcers or punishers because local rates of reinforcement could not be calculated unequivocally for these schedules.

Most of the data were analyzed by a two-way within-subjects analysis of variance (within-schedule variable by between-schedule variable). The few studies that could not be analyzed this way were analyzed either by a t test or by a one-way within-subject analysis of variance. The results of the one-way ANOVAs have been distinguished from those of the two-way tests by placing an asterisk following the results of a one-way analysis when presenting the data. Whenever a study had more than one part (e.g., Experiments 1 and 2), the parts were analyzed separately. The statistics corresponding to each part have been labeled when presenting the data.

Several conventions were followed in analyzing the data. First, every schedule that the authors presented as a separate schedule was treated as a separate schedule. For example, if a concurrent variable-interval one-minute variable-interval four-minute (concurrent VI 1-min VI 4-min) schedule was conducted twice, the results of each presentation were included as a separate schedule in the statistical test.

Second, schedules were not included in the analysis of local rates of reinforcement if extinction was arranged during one component. These schedules were ignored because the local rate of reinforcement could not vary during this component.

Third, schedules were ignored in the analysis of both responding and reinforcement if the subjects did not respond during one component. Again, the local response and reinforcement rates could not vary during such components.

Finally, whenever information was missing from a cell of an analysis of variance (e.g., if some subjects did not respond on a particular schedule), that level of the variable was eliminated for all subjects.

The rest of this paper summarizes the results of these analyses of variance. The actual values of the tests appear in the appendices. Appendix A contains F-tests, which compared the local rates of responding and reinforcement during the two components of single concurrent schedules. Appendix B contains F-tests comparing the local rates of responding and reinforcement across the components of different concurrent schedules. Appendix C contains a list of the significant interactions found while conducting the analyses of variance. Only significant interactions have been listed in Appendix C because very few occurred. Interactions have been listed and will not be discussed because each may require a separate explanation.

The headings in the Appendices are self-explanatory, except for the labels "asymmetrical changeover ratios" and "favorability of component." Studies using asymmetrical changeover ratios (CORs) required a different number of responses to change from one component of the concurrent schedule to the other than to change back again. The components of concurrent schedules differed in favorability if they provided different programmed rates of reinforcement. A component of a concurrent schedule was considered more favorable than the other component if it was the component that provided the higher programmed rate of reinforcement when independent interval schedules were used. It was the component that provided the higher proportion of programmed reinforcers when interdependent schedules were used (cf. Stubbs & Pliskoff, 1969).

Although the Appendices contain the results of many studies, studies are discussed in the text only when relatively clear conclusions can be drawn. Conclusions are not discussed if they are supported by the results of only one or two studies. For example, the effect of deprivation for the programmed reinforcers is not discussed because only one study examined this variable (Willis, Van Hartesveldt, Loken, & Hall, 1974). Conclusions are also omitted if the data conflict and insufficient data are available to resolve the conflict. For example, local rates of responding sometimes differed between the components and sometimes did not when the components provided different reinforcers or required different responses. However, these variable are not discussed because too few studies have been conducted to allow clear conclusions to be drawn about the factors that produced the differences in results. Finally, conclusions are not discussed if they are obvious. For example, the obtained local rates of reinforcement decreased with increases in the duration of the changeover delay (COD). But, the COD must reduce obtained rates of reinforcement as it gets longer because it is a period of time during which no reinforcers are given.

LOCAL RATES OF REINFORCEMENT OBTAINED FROM THE TWO COMPONENTS OF CONCURRENT SCHEDULES

The Equalizing Principle states that the local rates of reinforcement obtained from the components of a single concurrent schedule will be equal. The data usually support this principle. Three differences between the components did not produce differences in the local rates of reinforcement obtained from the components.

First, the local rates of reinforcement obtained from the components did not differ when the components supplied two different types of reinforcers. The reinforcers studied included food and brain stimulation (Hollard & Davison, 1971), food and water (Willis et al., 1974), and several different types of foods (Matthews & Temple, 1979; Miller, 1976). Therefore, this conclusion has some generality.

Second, no study reported a significant difference between the local rates of reinforcement when the components differed in only minor ways, such as the discriminative stimuli used to signal the components or the position of the operanda that produced reinforcers (Marcucella & Margolius, 1978; McSweeney & DeRicco, 1976; White, 1979, Experiment 1).

Third, the local rates of reinforcement were not generally different when the components differed in favorability. Appendix A shows that 14 tests of significance supported the Equalizing Principle by finding equal rates of reinforcement. Five violated it by finding significantly higher local rates of reinforcement during the more favorable component than during the less favorable one. The studies reporting different results were similar in several ways, ruling them out as explanations of the different results (e.g., species of subjects used, type of concurrent procedure used, number of schedules conducted, and degree of difference in favorability between the components). However, studies did differ in the length of the COD used. No study that used a COD longer than 2 sec reported significant differences and the average COD duration was longer in studies that did not report a significant difference (mean = 7.2 sec) than in those that did (mean = 1.4 sec).

Figure 1 examines the relationship between the Equalizing Principle and COD duration in more detail. It contains the ratio of the local rates of reinforcement obtained from the components of a concurrent VI 1-min VI 3-min schedule in Shull and Pliskoff (1967), plotted as a function of COD duration in seconds. Shull and Pliskoff found a significant effect of favorability of component [$F(1,1) = 741.58$, $p < .025$], but their results were not reported in Appendix A because the number of responses, reinforcers, and time spent responding on a component did not always come from the same session. Therefore, to calculate a local reinforcement rate, the number of reinforcers obtained during a component in Session 2 might be divided by the time spent responding on that component during Session 4. Shull and Pliskoff's results are presented here because they provide the only statistically significant evidence about changes in local reinforcement rates when the COD varied over a wide range.

Bearing in mind this limitation on the data, Figure 1 shows that the local rates of reinforcement obtained from the components are more similar (ratios approaching 1.0) when the COD is long than when it is short (ratios greater than 1.0), supporting the hypothesis that the Equalizing Principle is violated only when COD durations are short.

Results conflicted when the effects of a fourth variable, type of operandum, was studied. Two studies supported the Equalizing Principle by finding no differences in local rates of reinforcement between the components when pigeons pecked keys in one component and pressed levers or treadles in the other (Davison & Ferguson, 1978; McSweeney, 1978, 0-sec and 5-sec CODs). Two studies violated the Equalizing Principle by finding a significant difference under similar circumstances (McSweeney, 1978, 20-sec COD; Wheatley & Engberg, 1978). In both cases higher local rates of reinforcement were usually obtained by pecking the key than by pressing the treadle.

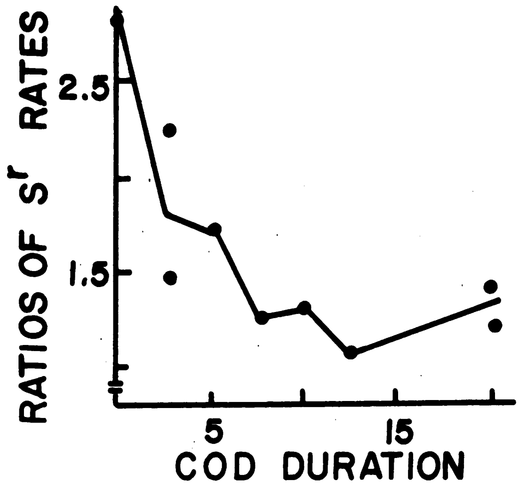

Fig. 1. Ratios of the local rates of reinforcement obtained from the components of a concurrent VI 1-min VI 3-min schedule plotted as a function of COD duration in seconds, for the mean of all subjects responding in Shull and Pliskoff (1967).

The most likely explanation for the differences in results is that the local rates of reinforcement obtained from the components differed early in training but obeyed the Equalizing Principle later. The studies producing different results used the same species of subject, type of operanda, type of reinforcers, and the same simple schedules. They did not differ systematically in length of COD, difficulty of pressing the treadles, or range of rates of reinforcement that were programmed for the components. But, the studies did differ in the length of time for which schedules were conducted. Wheatley and Engberg (1978), who reported significant differences, conducted many fewer sessions per schedule (16 on the average, with a range from 9 to 23) than the two studies that did not find a difference. Davison and Ferguson (1978) conducted 25 sessions on the average, with a range from 17 to 38; and McSweeney (1978) conducted 35 on the average, with a range from 21 to 54. Therefore, differences in the local rates of reinforcement may appear early in training but disappear later.

Differences in the number of sessions conducted per schedule does not provide a complete explanation, however. It does not explain the results of McSweeney (1978) when the COD was 20 sec. Although subjects did conform to the Equalizing Principle when the COD was 0 or 5 sec in that study, even extended training did not produce equalizing when the COD was 20 sec. Only further research will explain this result.

Results usually violated the Equalizing Principle when different types of simple schedules appeared in the components. Higher local rates of reinforcement were obtained from fixed ratio (FR) than from VI schedules (Bacotti, 1977) and from fixed interval (FI) than from VI schedules (Trevett, Davison, & Williams, 1972). In other cases, different simple schedules produced different local rates of reinforcement, but the direction of the difference depended on the choice of parameters for the schedules. Herrnstein and Heyman (1979) found that subjects obtained a higher local rate of reinforcement during VR components than during VI components for some choices of parameters, but they did not respond on the VR component for other choices. Rider (1979) found that subjects obtained a higher local rate of reinforcement from VR than from FR schedules when both required the same 50 responses for reinforcement.

In two cases, results conformed to the Equalizing Principle even when different schedules were used in the components (Lobb & Davison, 1975; Rider, 1979, concurrent FR MR schedules). Rider's results are not surprising. He did not find significant differences in the local rates of reinforcement obtained from FR and mixed ratio (MR) components. But,' the MR schedules, which were made up of only two different fixed ratios, differed little from the FR schedules. Lobb and Davison's results are puzzling, however. They differed from those of Trevett et al. (1972) even though the two studies used very similar procedures. The studies used the same reinforcers, CODs, species of subjects, stability criteria, and many of the same schedules. The only noticeable difference was that Lobb and Davison used a Findley procedure, whereas Trevett et al. used a two-operanda procedure. During a Findley procedure, subjects respond on only one operandum to produce reinforcers for both components. They change components by responding on a second operandum. During two-operanda concurrent schedules, subjects respond on two different operanda to obtain reinforcers for the two components. They change components by moving from one operandum to the other. Further studies should investigate whether local rates of reinforcement are more likely to differ between FI and VI components when a two-operanda, but not a Findley, procedure is used.

To summarize, the Equalizing Principle was generally supported when a long COD (greater than 2 sec) was used and many sessions (more than 25) were conducted. The local rates of reinforcement obtained from the components of a concurrent schedule generally did not differ in spite of differences between the components in the reinforcer, discriminative stimuli, position of operanda, favorability of the component, and type of operanda used. The results violated the Equalizing Principle when the components provided two different simple schedules of reinforcement. In some cases, the simple schedule that provided the higher rate of reinforcement depended on the choice of parameters for the two different schedules.

LOCAL RATES OF RESPONDING EMITTED DURING THE TWO COMPONENTS OF CONCURRENT SCHEDULES

The local rates of responding emitted during the two components of a concurrent schedule were frequently different. Only two factors did not produce a difference. First, local response rates did not differ when the components differed only in minor ways such as the discriminative stimuli used or the position of the operanda that produced reinforcers (Marcucella & Margolius, 1978; McSweeney & DeRicco, 1976; White, 1979, Experiment 1). Second, the local rates of responding did not differ when the components differed in favorability and a long COD was used.

Appendix A shows that differences in favorability between the components of a concurrent schedule produced statistically significant differences in local response rates in 6 cases but not in 17 others. Again, the difference in results may be attributed to differences in COD duration. Several variables could not have produced the differences because they did not differ systematically between the studies reporting and failing to report an effect. The different studies did not differ in the use of Findley or two-operanda procedures, the use of a COR instead of a COD, or the degree of difference in favorability between the components. But, the studies did differ in the duration of the COD. Studies that reported a significant difference in local response rates used a shorter COD (mean = 1.9 sec) than those which did not (mean = 6.6 sec); and no study reporting an effect used a COD longer than three sec. Differences in local rates of responding, like differences in local rates of reinforcement, may appear only when a short COD is used.

Another variable, the simple schedule provided by the components, produced different local rates of responding in the two components. Local response rates did not differ when both components provided either ratio (Rider, 1979) or interval schedules (Lobb & Davison, 1975; Trevett et al., 1972), but they did differ when one provided a ratio and the other an interval schedule. Bacotti (1977) found higher local rates of responding during FR than during VI components when the VI schedule was held constant at 4 min and the FR requirement varied from 25 to 100. Herrnstein and Heyman (1979) found higher local rates of responding during VR than during VI schedules when the VI component was either a VI 30-sec or VI 40-sec schedule and the VR component was either VR 30 or VR 45. LaBounty and Reynolds (1973) reported higher local rates of responding during FR than during FI schedules, when the FI component was held constant at FI 4-min and the FR requirement varied from 100 to 300.

To summarize, the local response rates emitted during the components of concurrent schedules were frequently, but not always, equal. They did not differ when the discriminative stimuli, position of operanda, or favorability of the conditions of reinforcement differed between the components and long CODs were used (longer than 3 sec). Local response rates were also equal when both components provided either interval or ratio schedules. But, the local rates of responding did differ when one component provided a ratio and one provided an interval schedule.

Differences Between Local Rates of Reinforcement across Schedules

Appendix B shows that the local rates of reinforcement generally changed with changes in the programmed schedule of reinforcement —in 17 of 19 studies. Only two studies failed to find a main effect of schedule of reinforcement (Miller, 1976; Pliskoff, Cicerone, & Nelson, 1978), and these failures probably occurred because of the way in which the studies were designed. Four of the five schedules studied in Replication 1 of Pliskoff et al., and two of the four schedules studied in Replication 2, were concurrent VI 2-min VI 6-min schedules. Local rates of reinforcement would be expected to change little if the schedules themselves changed little from point to point. Miller varied both the rate of reinforcement and the type of grain obtained from the components. Therefore, increases in the local rates of reinforcement that occurred when the programmed rate of reinforcement increased may have been offset by decreases in the local rates that occurred when a less preferred grain was substituted for a more preferred one.

Figure 2 shows that the local rates of reinforcement obtained from concurrent schedules changed with changes in the rates of reinforcement programmed for the schedule when the components provided interval schedules. The figure presents the sum of the local rates of reinforcement obtained from the two components, plotted as a function of the sum of the rates of reinforcement programmed for those components. Sums have been plotted instead of rates during individual components because the rate of reinforcement programmed for one component did not vary in several studies, and because the sums changed as a more orderly function of the programmed rates of reinforcement than the rates of reinforcement obtained from individual components. The data represent the mean of all subjects responding in experiments that included more than three schedules. The equation of the least-squares regression line appears on each graph followed by the correlation coefficient in parentheses.

The sum of the local rates of reinforcement increased with increases in the sum of the programmed rates of reinforcement, and the function appears to be linear over the rates studied. These studies used both Findley and two-operanda procedures, rats and pigeons, food and brain stimulation, FI and VI component schedules. Therefore, the results have some generality.

Figure 2 shows that the changes in the obtained local rates of reinforcement were correlated with changes in schedule parameters. But, the high correlations reported in Figure 2 should not be misinterpreted. Calculating programmed and obtained local rates of reinforcement for a wide variety of schedules and assumptions about responding, shows that the correlation between the obtained and programmed rates of reinforcement must be 1.0 for concurrent-interval interval schedules if some simplifying assumptions are made about behavior. Correlations will be 1.0 if subjects devote reasonable amounts of time to responding on both components and if they collect all reinforcers as soon as they become available. Collecting all reinforcers immediately requires that subjects respond at a fairly high steady

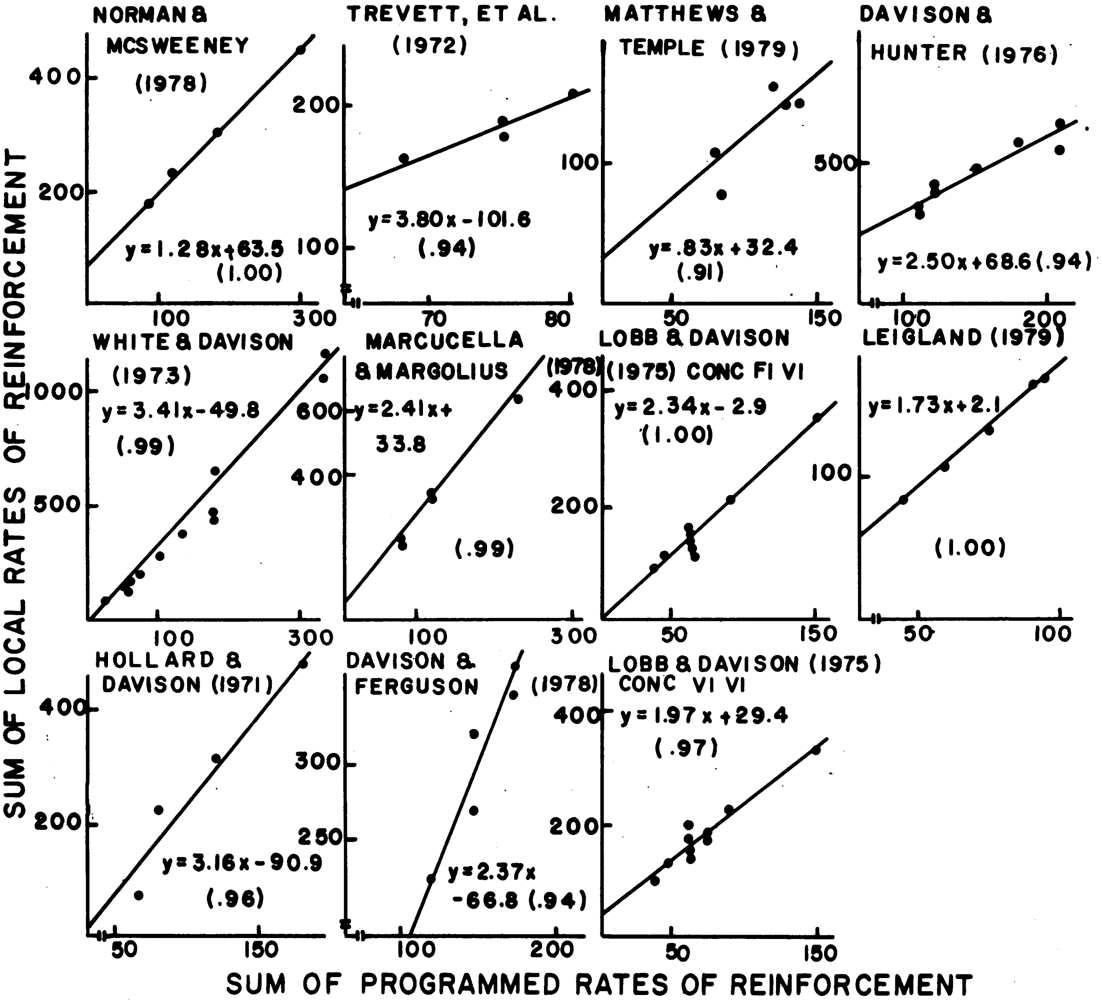

Fig. 2. Sum of the obtained local rates of reinforcement (reinforcers per hour) plotted as a function of the sum of the programmed rate of reinforcement (reinforcers per hour) for the mean of all subjects responding on each concurrent schedule in several different studies.

rate on both components and that they switch frequently between them. Therefore, although Figure 2 provides a description of an important relationship between the programmed and obtained local rates of reinforcement, this relationship should not be over-interpreted. High correlations must occur for concurrent-interval interval schedules if subjects follow a relatively simple strategy of responding.

Figure 3 shows that the local rate of reinforcement obtained from a ratio component of a concurrent schedule decreased with increases in the ratio requirement. Again, the data represent the mean of the local rates obtained for all subjects responding during concurrent schedules that provided a ratio component. Data have been provided for single components rather than as sums because none of the present studies provided ratio schedules during both components. Bacotti (1977) varied the COD. His data have been presented separately for different COD durations. Again, the results have some generality because both pigeons and rats served as subjects, and Findley and two-operanda procedures were used.

To summarize, the obtained local rates of reinforcement changed with changes in the schedule of reinforcement. The sum of the local rates of reinforcement increased with increases in the sum of the programmed rates when interval schedules were used. The obtained rates of reinforcement decreased with

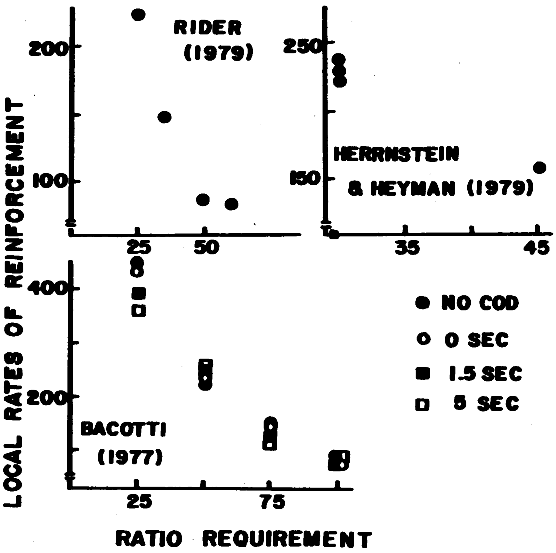

Fig. 3. Local rates of reinforcement (reinforcers per hour) obtained from ratio components plotted as a function of the ratio requirement, for the mean of all subjects responding in three different experiments.

increases in the ratio requirement when ratio schedules were used.

Differences Between Local Rates of Responding Across Schedules

Appendix B shows that the local rates of responding generally changed with changes in the programmed schedule of reinforcement. The programmed schedule of reinforcement exerted a statistically significant effect on the local rates of responding in 9 cases but not in 23 others.

The most likely explanation for the difference in results is a systematic difference between the studies in the range of the sum of the rates of reinforcement that were programmed for the components. The studies producing different results did not differ in species of subjects and degree of favorability of the components, ruling out these variables as explanations for the differences in results. But, the studies did differ in the range of the sum of the overall rates of reinforcement programmed for the components. The range was greater for the studies reporting an effect (180.3 reinforcers per hour on the average) than for those not reporting an effect (55.1 reinforcers per hour on the average). Three of the studies that did not report an effect did not vary the sum of the programmed rates of reinforcement at all (Miller, 1976; Pliskoff et al., 1978; Stubbs & Pliskoff, 1969). Therefore, the local rates of responding may change with changes in the schedule only when the rates of reinforcement programmed for the schedule vary over a wide range.

Differences in the range of rates of reinforcement do not provide a complete explanation for the differences in results, however. They cannot explain the studies that reported an effect in some conditions but not in others. McSweeney (1978) found an effect when no COD separated the components of a concurrent key-peck treadle-press schedule but did not find an effect when 5-sec or 20-sec CODs were used. Wheatley and Engberg (1978) found an effect when subjects responded on a concurrent treadle-press treadle-press schedule but not when they responded on a concurrent key-peck treadle-press schedule. Rider (1979) found an effect when subjects responded on a concurrent FR VR schedule but not when they responded on a concurrent FR MR schedule. And Trevett et al. (1972) found an effect when subjects responded on a concurrent FI VI schedule but not when they responded on a concurrent VI VI schedule. Not only did these studies fail to differ systematically in the range of programmed rates of reinforcement, but Trevett et al. and Wheatley and Engberg reported an effect when they held the sum of the programmed rates of reinforcement constant. The reason for the different results in different parts of these experiments is not known.

Figure 4 helps to clarify the relationship between the schedule of reinforcement and the local rate of responding for the studies that conducted at least four schedules and in which the range of the sum of the local rates of reinforcement was 130 reinforcers per hour or more. The median of the range of rates of reinforcement used in all studies was approximately 130 reinforcers per hour.

Figure 4 presents the sum of the local rates of responding emitted during the components plotted as a function of the sum of the local rates of reinforcement obtained from those components. The least-squares fit line and the correlation coefficients (in parentheses) appear on each graph. Sums were plotted instead of data for individual components because the rate of reinforcement obtained from particular components varied little in some studies. Responding was plotted as a function of the ob-

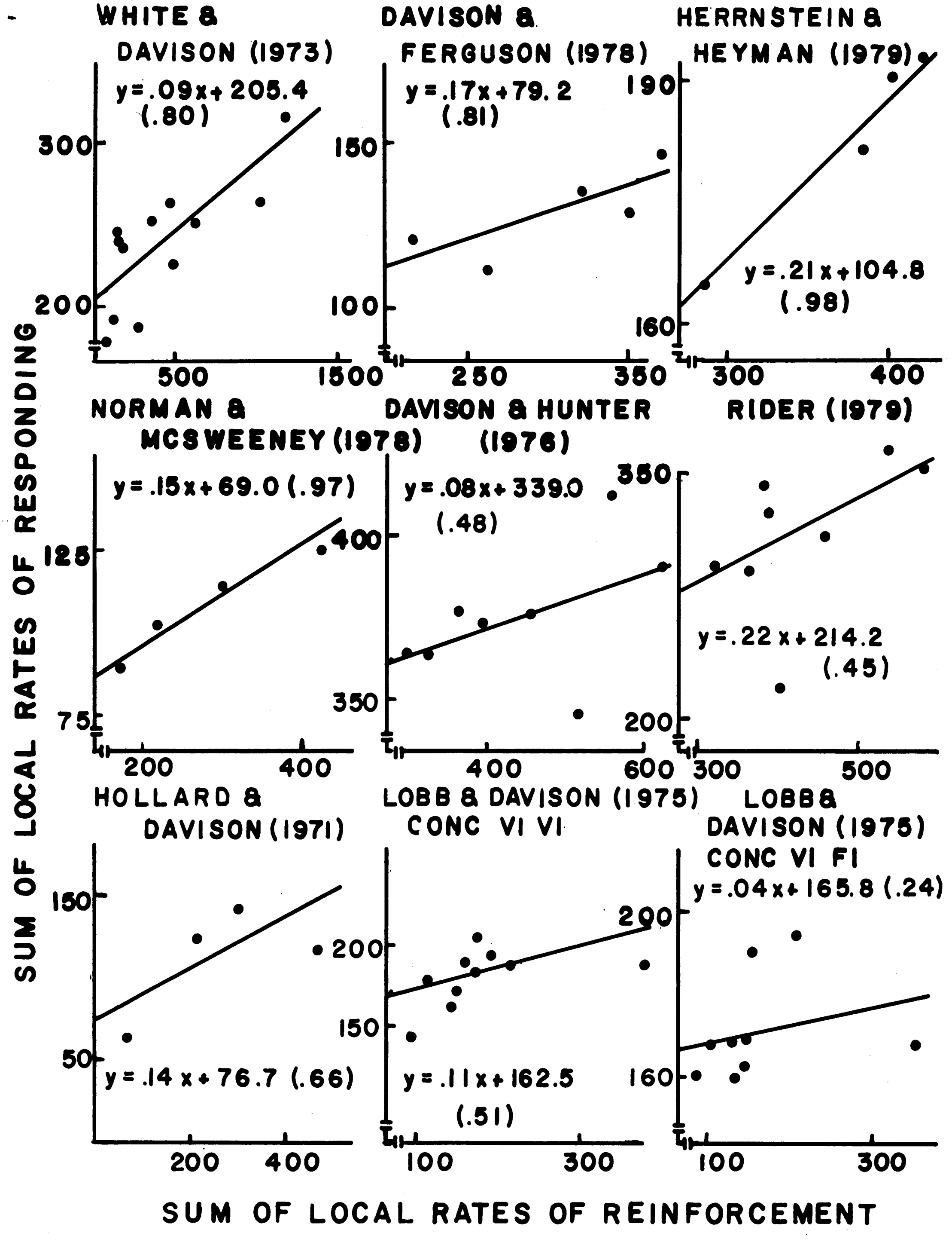

Fig. 4. Sums of the local rates of responding (responses per minute) emitted during the components of concurrent schedules, plotted as a function of the sums of the local rates of reinforcement (reinforcers per hour) obtained from the components, for the mean of all subjects responding in all experiments that conducted at least four schedules and for which the range of the sum of the obtained local rates of reinforcement was at least 130 reinforcers per hour.

tained, rather than the programmed, rates of reinforcement because response rates were slighlty more highly correlated with the obtained than with the programmed rates. However, the extremely high correlation between the obtained and programmed rates of reinforcement, shown in Figure 2, indicates that the choice of abscissa makes little difference. Figure 4 shows that the sum of the local rates of responding increases as a linear function of the sum of the obtained local rates of reinforcement.

Appendix B also shows that the length of the COD had little effect on the local rates of responding, but the COR requirement did have an effect. The effect of the COD or COR on local response rates was not significant in 12 of the cases reported in Appendix B, but it was in two others. The statistically significant effects both occurred in a study that used a COR rather than a COD. Figure 5 clarifies the relationship between the local rates of responding and the COR for this study (White, 1979). It presents the local rates of responding in responses per min plotted as a function of COR for Experiment 1 and as a function of the ratio of the CORs for the two components in Experiment 2. Experiment 2 provided different requirements for switching from one component to the other than for switching back again. The abscissa of the graph for Experiment 2 represents the ratios of these requirements. In both graphs, the data represent the mean of all subjects; unfilled circles represent one component; filled circles represent the other.

Figure 5 shows that the local rates of responding during both components in Experiment 1 increased with increases in the COR. The local response rates during the components in Experiment 2 increased and became more different as the CORs separating the components became more different.

Appendix B and Figure 5 show that the local rates of responding changed significantly with changes in the COR but not the COD. However, these changes may be a byproduct of the effect of the COD and COR on the local rates of reinforcement. Changes in the local rates of reinforcement with changes in the COR and COD were not discussed because both the COD and COR make it more difficult to obtain reinforcers and therefore must reduce the local rate of reinforcement if they become severe enough. However, the CODs and CORs used in practice may not always be severe enough to reduce local rates of reinforcement. Examination of Appendix B shows that changes in the CORs, but not the CODs, used in the present studies changed the local rates of reinforcement significantly. Two of the three studies that reported a significant effect of the COD or COR on the obtained local rates of reinforcement varied the COR rather than the COD (Stubbs & Pliskoff, 1969; White, 1979, Experiment 2). Only one of the six studies that did not report a significant effect varied the COR (White, 1979, Experiment 4). Because Figure 4 showed that the local rates of responding and reinforcement are correlated, the pres-

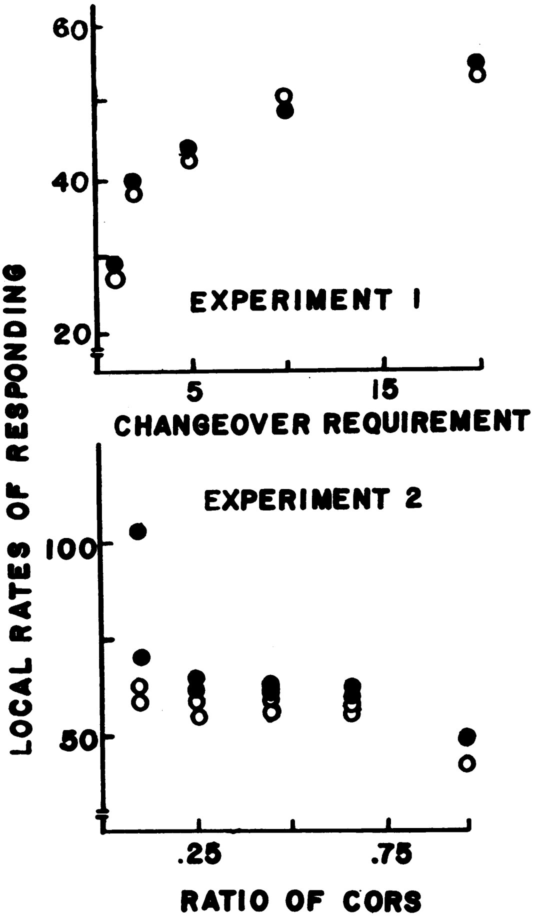

Fig. 5. Local rates of responding (responses per minute) plotted as a function of the COR for White (1979, Experiment 1) and as a function of the ratio of the CORs for White (1979, Experiment 2). The data represent the mean of all subjects in each experiment. Filled circles represent one component; unfilled circles represent the other.

ent effect of the COR, but not the COD, on local response rates may have resulted from their effect on the local rates of reinforcement.

To summarize, local rates of responding did not change with changes in COD duration but did change with changes in the COR requirement and with changes in the obtained local rates of reinforcement. Local rates of responding increased with increases in the COR requirement, and they increased and became more different as the CORs separating the components became more different. The sum of the local rates of responding also increased with increases in the sum of the obtained local rates of reinforcement.

IMPLICATIONS

The present results have a number of methodological and theoretical implications in addition to their specific implications about the factors that control the local rates of responding and reinforcement. First, methodologically, the data are more orderly when concurrent schedules employ long CODs and when they include a large number of sessions for each schedule. The exact duration of COD and number of sessions cannot be specified without further investigation. The present results suggest that a COD of approximately 3 sec, and approximately 30 sessions per schedule, are required to equate both the local rates of responding and reinforcement between the components.

Second, the results generally violate the assumption that the relative rates of responding and the relative time spent responding on the components of concurrent schedules are equivalent measures of behavior. As noted earlier, this assumption has been questioned in the past (e.g., Baum, 1979). But, the circumstances under which the two measures differ significantly have not been established. The present results help to identify these circumstances because the two measures of behavior are equal only when the local rates of responding emitted during the components are equal. The present data showed that the local rates of responding were equal only when both components of the concurrent schedule provided either ratio or interval schedules and differed only in other minor ways such as the discriminative stimuli that signaled them or the position of the operanda that produced reinforcers. Local response rates were frequently different when one component provided a ratio and the other an interval schedule, and Appendix A shows that they sometimes differed when the components provided different operanda or reinforcers. Therefore, the relative rates of responding and the relative time spent responding were not equivalent measures of behavior under these circumstances.

Third, the data generally support the Equalizing and Melioration Principles. The data conform to the Equalizing Principle, and therefore to an implication of the Melioration Principle, for schedules that used long CODs and were in effect for many sessions. Violations of these principles occurred during concurrent schedules that provided different simple schedules in the components. Therefore, the Equalizing and Melioration Principles provide good descriptions of many data.

Fourth, the success of the Equalizing and Melioration Principles helps to clarify the need for Baum's *a* and *b* parameters when the relative time spent responding is the measure of behavior. As argued earlier, Baum (1979) reviewed the literature and found little evidence that the exponent of Equation 2 differs from 1.0 when the relative time spent responding was plotted as a function of the relative rate of reinforcement. Mullins et al. (1982) reviewed the same literature using a different statistical test and concluded that the exponent was less than 1.0. Again, the *a* and *b* parameters of Baum's equation do not deviate significantly from 1.0 whenever Equalizing is supported. Therefore, the present data suggest that the conclusion of Mullins et al. will be supported whenever statistical tests favor data from studies that use short CODs, conduct few sessions per schedule, or provide different schedules in the two components. Baum's conclusions will be supported for other studies.

By supporting the Equalizing Principle at some times but not at others, the present data also provide information about the factors that control the size of Baum's *a* and *b* parameters when the relative time spent responding is plotted as a function of the relative rate of reinforcement. The present data are consistent with Baum's speculation that using qualitatively different schedules in the two components and using short-duration CODs may produce deviation of *a* or *b* from 1.0. The present analysis is inconsistent with Baum's speculation that using qualitatively different reinforcers in the two components produces parameters that differ from 1.0 (Baum, 1974; Baum, 1979). Subjects equated the local rates of reinforcement obtained from the components in all of the present studies that provided qualitatively different reinforcers in the two components. Therefore, *a* and *b* did not differ significantly from 1.0. Future studies should determine whether Baum's speculation is incorrect, or whether the present studies generated too few or too variable data, or did not choose reinforcers that differed enough to produce significant differences.

Although studying the Equalizing Principle can provide information about Baum's *a* and *b* parameters, it should be noted that it cannot provide a complete analysis of the data. Violations of the Equalizing Principle indicate that either *a* or *b* or both differed significantly from 1.0. They do not indicate which parameter deviated. The data must be examined according to Equation 2 to provide that information. When the data are plotted according to Equation 2, the results of past studies supplement the results of the present analysis by suggesting that both *a* and *b* deviated from 1.0 for concurrent FI FR schedules (LaBounty & Reynolds, 1973, as replotted in Baum, 1974), for concurrent VI FI schedules (Lobb & Davison, 1975; Trevett et al., 1972), and for concurrent FI VR schedules (Rider, 1981). Past studies also suggest that the *b*, bias, parameter but not the *a*, undermatching, parameter differs from 1.0 for concurrent FR VI schedules (Bacotti, 1977) and for concurrent VI VR schedules (Herrnstein, cited in Baum, 1974). Finally, past studies suggest that changing the COR changes the undermatching parameter (Pliskoff & Fetterman, 1981).

Fifth, the data generally violate Herrnstein's Matching Law (Equation 1). As noted earlier, data conform to Herrnstein's equation when the local rates of responding and the local rates of reinforcement are both equal between the components. This was rarely true. Both local rates were equal only during concurrent schedules in which the components differed in only minor ways such as the discriminative stimuli used or the position of the operanda.

Violations of Herrnstein's equation may provide information about the size of Baum's *a* and *b* parameters when the relative rate of responding is plotted as a function of the relative rate of reinforcement. The data conform to Herrnstein's equation when *a* and *b* equal 1.0; they violate it at other times. Therefore, the present analysis supports Baum's speculation that differences between the components in the operanda that produce reinforcers or in the schedule of reinforcement produce *a* or *b* parameters that differ from 1.0. It also supports Baum's speculation that using a short COD produces an *a* parameter that differs from 1.0. But, the present analysis provides only limited support for Baum's speculation that the bias or undermatching parameters differ from 1.0 when two different reinforcers appear in the components (Baum, 1974; Baum, 1979). The local rates of responding did differ significantly in one study that employed two different reinforcers, indicating that *a* or *b* or both differed from 1.0. But again, it is not clear whether Baum's idea is of limited generality or whether the present studies produced too few or too variable data, or used reinforcers that were too similar to produce a statistically significant difference.

The present analysis can provide information about the size of Baum's *a* and *b* parameters when the relative rate of responding is plotted as a function of the relative rate of reinforcement, but it cannot provide a complete description of the data. Deviations of the data from Herrnstein's equation indicate that either *a* or *b* or both differed from 1.0; the data must be plotted according to Equation 2 to determine which. Past studies that have plotted the data according to Equation 2 have suggested that both *a* and *b* differ from 1.0 during concurrent VI FI (Lobb & Davison, 1975; Nevin, 1971; Trevett et al., 1972), and concurrent FI VR (Rider, 1981) schedules. They have argued that the undermatching, but not the bias parameter, differs from 1.0 during concurrent FI FR schedules (LaBounty & Reynolds, 1973, as reanalyzed by Baum, 1974) and that the bias, but not the undermatching, parameter differs from 1.0 during concurrent FR VI (Bacotti, 1977) and concurrent VI VR (Herrnstein, cited in Baum, 1974) schedules. Past studies have also indicated that changing the COR changes the size of the undermatching parameter (Pliskoff & Fetterman, 1981).

Sixth, the present results are consistent with, but do not compel, the conclusion that subjects conform to the Matching Laws because they regulate local rates of responding and reinforcement. Herrnstein and Vaughan (1980) have proposed that some of the regularities in concurrent-schedule responding result from subjects equating the local rates of reinforcement obtained from the components. The present analysis is consistent with this idea in many cases and goes beyond it to suggest that equating the local rates of reinforcement may produce further regularities in behavior because the local rates of reinforcement are highly correlated with the local rates of responding.

Finally, the present data suggest that the changes in the local rates of responding and reinforcement across schedules may be orderly. Systematic changes in both measures were found with changes in the schedule requirements and with changes in the COR. These orderly changes deserve much more study, particularly because no current theory accurately describes the absolute rates of responding emitted during the components of concurrent schedules (cf. McSweeney et al., in press). Past theories, such as Herrnstein's (1970), have typically described overall rates of responding, but two considerations suggest that local response rates may also merit analysis. First, the systematic changes in local rates that occurred with changes in the schedule in the present paper suggest that the local rates may be orderly. Second, the assumption that led Herrnstein to formulate his equation in terms of overall instead of local rates appears in retrospect to be incorrect. Herrnstein looked for order in the overall rates because he assumed that the equation for the absolute rates of responding emitted during the components of concurrent schedules must yield Equation 1 when their ratio is taken. Equation 1 would follow if the overall rates were used because the time denominators would be equal for the two components and would cancel when the ratios were taken. Equation 1 would not follow using local rates because the time denominators used to calculate local rates would not usually be equal and would not cancel. The frequent failure of Equation 1 makes his argument less compelling and suggests that future experimenters should look for order in local as well as overall rates.

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APPENDIX A

Comparison of the local rates of reinforcement obtained from and the local rates of responding emitted during the components of a concurrent schedule. Tests that were not significant have been listed immediately under each heading, followed by those that were significant.

Study	*Result*	*Significance*
Local Rates of Reinforcement		
Favorability of the Component		
Allison & Lloyd (1971), Experiment 1	$F(1,3) = 0.33$	$p > .05$
Experiment 2	$F(1,3) = 4.52$	$p > .05$
Lobb & Davison (1975), conc VI VI schedules	$F(1,9)^{*} = 1.42$	$p > .05$
Miller & Loveland (1974)	$F(4,12)^{*} = 0.80$	$p > .05$
Norman & McSweeney (1978)	$F(1,4) = 0.82$	$p > .05$
Pliskoff et al. (1978), First Replication	$F(1,2) = 11.06$	$p > .05$
Second Replication	$F(1,2) = 1.22$	$p > .05$
Silberberg & Schrot (1974), Experiment 1	$F(1,3) = 3.40$	$p > .05$
Experiment 2	$F(1,3) = 4.71$	$p > .05$
Stubbs & Pliskoff (1969), schedules for which reinforcer proportion varied	$F(1,2) = 6.98$	$p > .05$
schedules for which COD varied	$F(1,2) = 15.97$	$p > .05$
Trevett et al. (1972), conc VI VI schedules	$F(1,3) = 0.33$	$p > .05$
Wheatley & Engberg (1978), conc treadle-press schedules	$F(1,1) = 15.37$	$p > .05$
White & Davison (1973)	$F(1,5) = 4.45$	$p > .05$
Davison & Hunter (1976)	$F(2,18)^{*} = 4.28$	$p < .05$
Heyman (1979)	$F(1,3) = 47.14$	$p < .01$
Killeen (1972)	$F(1,3) = 10.91$	$p < .05$
Leigland (1979)	$F(1,4) = 43.99$	$p < .01$
Stubbs & Pliskoff (1969), schedules for which the COR varied	$F(1,2) = 60.71$	$p < .025$
Asymmetrical Changeover Ratios (CORs)		
White (1979), Experiment 4	$F(1,1) = 27.81$	$p > .05$
Experiment 2	$F(1,2) = 30.56$	$p < .05$
Type of Schedule		
Lobb & Davison (1975), conc FI VI	$F(1,8)^{*} = 4.60$	$p > .05$
Rider (1979), conc FR MR	$F(1,2) = 0.38$	$p > .05$
Bacotti (1977), conc VI 4-min FR 25	$F(1,3) = 88.92$	$p < .01$
conc VI 4-min FR 50	$F(1,3) = 127.32$	$p < .01$
conc VI 4-min FR 75	$F(1,3) = 40.09$	$p < .01$
conc VI 4-min FR 100	$F(1,2) = 26.34$	$p < .05$
Herrnstein & Heyman (1979), conc VI VR, for schedules in which subjects responded in the VR component	$F(1,3) = 23.16$	$p < .05$
Rider (1979), conc VR FR	$F(1,3) = 18.95$	$p < .025$
Trevett et al. (1972), conc FI VI	$F(1,3) = 38.46$	$p < .01$
Type of Operanda		
Davison & Ferguson (1978), conc key peck lever press	$F(1,4) = 4.60$	$p > .05$
McSweeney (1978), conc key peck treadle press		
0-sec COD	$F(1,3) = 1.04$	$p > .05$
5-sec COD	$F(1,3) = 2.78$	$p > .05$
McSweeney (1978), conc key peck treadle press, 20-sec COD	$F(1,3) = 13.54$	$p < .05$
Wheatley & Engberg (1978), conc key peck lever press	$F(1,2) = 73.42$	$p < .025$
Type of Reinforcer		
Hollard & Davison (1971), food vs. brain stimulation	$F(1,2) = 9.58$	$p > .05$
Matthews & Temple (1979), hay vs. meal only	$F(1,5) = 1.83$	$p > .05$
Miller (1976), hemp vs. buckwheat	$F(1,3) = 0.14$	$p > .05$
wheat vs. buckwheat	$F(1,3) = 8.30$	$p > .05$
hemp vs. wheat	$F(1,3) = 2.67$	$p > .05$
Willis et al. (1974), food vs. water	$F(1,3) = 4.76$	$p > .05$
Discriminative Stimulus or Position of Operanda		
Marcucella & Margolius (1978)[1]	$F(1,2) = 11.41$	$p > .05$
McSweeney & DeRicco (1976)	$F(1,3)^{*} = 0.43$	$p > .05$
White (1979), Experiment 1	$F(1,3) = 0.10$	$p > .05$

Study	*Result*	*Significance*
Local Rates of Responding *Favorability of the Component*		
Allison & Lloyd (1971), Experiment 1	$F(1,3) = 2.21$	$p > .05$
Experiment 2	$F(1,2) = 16.52$	$p > .05$
Davison & Hunter (1976)	$F(2,52)^* = 2.48$	$p > .05$
Leigland (1979)	$F(1,4)^* = 0.00$	$p > .05$
Miller & Loveland (1974)	$F(4,12)^* = 1.90$	$p > .05$
Miller et al. (1980), 0-degree disparity	$F(1,1) = 0.86$	$p > .05$
15-degree disparity	$F(1,1) = 0.12$	$p > .05$
45-degree disparity	$F(1,1) = 0.25$	$p > .05$
Norman & McSweeney (1978)	$F(1,4) = 0.51$	$p > .05$
Pliskoff et al. (1978), First Replication	$F(1,2) = 6.66$	$p > .05$
Silberberg & Schrot (1974), Experiment 1	$F(1,3) = 0.20$	$p > .05$
Experiment 2	$F(1,3) = 0.37$	$p > .05$
Stubbs & Pliskoff (1969)		
Reinforcer proportion varied	$F(1,2) = 5.21$	$p > .05$
COD varied	$F(1,2) = 0.00$	$p > .05$
COR varied	$F(1,2) = 2.30$	$p > .05$
Wheatley & Engberg (1978), conc treadle-press schedules	$F(1,1) = 0.35$	$p > .05$
White & Davison (1973)	$F(1,5) = 0.66$	$p > .05$
Beale & Winton (1970)	$t(5) = 7.67$	$p < .01$, 2-tailed
Heyman (1979)	$F(1,3) = 21.37$	$p < .025$
Killeen (1972)	$F(1,3) = 20.76$	$p < .025$
Lobb & Davison (1975), conc VI VI	$F(1,9)^* = 72.43$	$p < .01$
Pliskoff et al. (1978), Second Replication	$F(1,2) = 116.53$	$p < .01$
Trevett et al. (1972), conc VI VI	$F(1,3) = 19.44$	$p < .025$
Asymmetrical Changeover Ratios (CORs)		
White (1979), Experiment 2	$F(1,2) = 10.49$	$p > .05$
Experiment 4	$F(1,1) = 1.44$	$p > .05$
Type of Schedule		
Lobb & Davison (1975), conc VI FI	$F(1,8)^* = 0.24$	$p > .05$
Rider (1979), conc FR VR	$F(1,3) = 0.41$	$p > .05$
conc FR MR	$F(1,2) = 0.24$	$p > .05$
Trevett et al. (1972), conc VI FI	$F(1,3) = 4.39$	$p > .05$
Bacotti (1977), conc VI 4-min FR 25	$F(1,3) = 86.97$	$p < .01$
conc VI 4-min FR 50	$F(1,3) = 41.73$	$p < .01$
conc VI 4-min FR 75	$F(1,3) = 20.92$	$p < .025$
conc VI 4-min FR 100	$F(1,2) = 21.30$	$p < .05$
Herrnstein & Heyman (1979), conc VR VI	$F(1,3) = 26.59$	$p < .025$
LaBounty & Reynolds (1973), conc FR FI	$F(1,5) = 17.47$	$p < .01$
Type of Operanda		
McSweeney (1978), conc key peck treadle press		
0-sec COD	$F(1,3) = 1.83$	$p > .05$
5-sec COD	$F(1,3) = 1.13$	$p > .05$
20-sec COD	$F(1,3) = 0.58$	$p > .05$
Davison & Ferguson (1978), conc key peck lever press	$F(1,4) = 53.73$	$p < .01$
Wheatley & Engberg (1978), conc key peck lever press	$F(1,2) = 365.00$	$p < .01$
Type of Reinforcer		
Hollard & Davison (1971), food vs. brain stimulation	$F(1,2) = 0.35$	$p > .05$
Matthews & Temple (1979), hay vs. meal only	$F(1,5) = 0.00$	$p > .05$
Miller (1976), hemp vs. buckwheat	$F(1,3) = 0.21$	$p > .05$
wheat vs. buckwheat	$F(1,3) = 0.47$	$p > .05$
hemp vs. wheat	$F(1,3) = 1.53$	$p > .05$
Willis et al. (1974), food vs. water	$F(1,3) = 29.36$	$p < .025$
Discriminative Stimulus or Position of Operandum		
Marcucella & Margolius (1978)[1]	$F(1,2) = 9.45$	$p > .05$
McSweeney & DeRicco (1976)	$F(1,3) = 3.72$	$p > .05$
White (1979), Experiment 1	$F(1,3) = 5.05$	$p > .05$

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[1] Marcucella and Margolius conducted several schedules in which the components provided different rates of reinforcement, but these schedules were not included in the data analysis because of incomplete data.

APPENDIX B

Comparisons of the local rates of responding and the local rates of reinforcement across concurrent schedules. Tests that were not significant have been listed immediately under each heading, followed by those that were significant.

Study	*Result*	*Significance*
Local Rates of Reinforcement		
Programmed Schedule of Reinforcement		
Miller (1976), hemp vs. buckwheat	$F(4,12) = 0.56$	$p > .05$
wheat vs. buckwheat	$F(4,12) = 2.14$	$p > .05$
hemp vs. wheat	$F(4,12) = 1.58$	$p > .05$
Pliskoff et al. (1978), First Replication	$F(4,8) = 3.15$	$p > .05$
Second Replication	$F(3,6) = 0.44$	$p > .05$
Davison & Ferguson (1978), Part 4	$F(4,16) = 9.26$	$p < .01$
Davison & Hunter (1976)	$F(9,18)^* = 11.62$	$p < .01$
Herrnstein & Heyman (1979)	$F(3,9) = 5.11$	$p < .025$
Heyman (1979)	$F(2,6) = 21.62$	$p < .01$
Hollard & Davison (1971)	$F(3,6) = 24.30$	$p < .01$
Killeen (1972)	$F(1,3) = 99.45$	$p < .01$
Leigland (1979)	$F(4,4)^* = 127.96$	$p < .01$
Lobb & Davison (1975), conc FI VI	$F(8,8)^* = 9.29$	$p < .01$
conc VI VI	$F(9,9)^* = 11.96$	$p < .01$
Marcucella & Margolius (1978)	$F(4,8) = 41.57$	$p < .01$
Matthews & Temple (1979)	$F(4,20) = 34.31$	$p < .01$
McSweeney (1978), 0-sec COD	$F(2,6) = 66.54$	$p < .01$
5-sec COD	$F(2,6) = 17.11$	$p < .01$
20-sec COD	$F(3,9) = 8.82$	$p < .01$
Norman & McSweeney (1978)	$F(3,12) = 30.32$	$p < .01$
Rider (1979), conc FR MR	$F(3,6) = 5.59$	$p < .05$
conc FR VR	$F(7,21) = 5.83$	$p < .01$
Stubbs & Pliskoff (1969), reinforcer proportion varied	$F(3,6) = 3.31$	$p < .025$
Trevett et al. (1972), conc FI VI	$F(7,21) = 5.04$	$p < .05$
conc VI VI	$F(3,9) = 8.64$	$p < .01$
Wheatley & Engberg (1978), conc key peck treadle press	$F(10,20) = 7.05$	$p < .01$
conc treadle press treadle press	$F(6,6) = 43.55$	$p < .01$
White & Davison (1973)	$F(11,55) = 23.89$	$p < .01$
Changeover Delay or Changeover Ratio		
Allison & Lloyd (1971), Experiment 1	$F(1,3) = 0.36$	$p > .05$
Experiment 2	$F(9,18) = 1.67$	$p > .05$
Bacotti (1977), conc VI 4-min FR 25	$F(2,6) = 0.25$	$p > .05$
conc VI 4-min FR 50	$F(2,6) = 0.05$	$p > .05$
conc VI 4-min FR 75	$F(2,6) = 1.23$	$p > .05$
conc VI 4-min FR 100	$F(3,6) = 0.28$	$p > .05$
Pliskoff (1971)	$F(18,18)^* = 0.13$	$p > .05$
Silberberg & Schrot (1974), Experiment 1	$F(1,3) = 7.48$	$p > .05$
Stubbs & Pliskoff (1969), when the COD varied	$F(3,6) = 1.00$	$p > .05$
White (1979), Experiment 4	$F(7,7) = 1.56$	$p > .05$
Silberberg & Schrot (1974), Experiment 2	$F(1,3) = 21.36$	$p < .025$
Stubbs & Pliskoff (1969), when the COR varied	$F(2,4) = 10.03$	$p < .025$
White (1979), Experiment 1	$F(4,12) = 4.56$	$p < .025$
Experiment 2	$F(8,16) = 3.23$	$p < .025$
Deprivation		
Willis et al. (1974)	$F(3,9) = 0.88$	$p > .05$
Local Rates of Responding		
Programmed Schedule of Reinforcement		
Herrnstein & Heyman (1979)	$F(3,9) = 1.31$	$p > .05$
Heyman (1979)	$F(2,6) = 0.79$	$p > .05$
Killeen (1972)	$F(1,3) = 4.17$	$p > .05$
LaBounty & Reynolds (1973)	$F(3,15) = 2.15$	$p > .05$
Leigland (1979)	$F(4,4)^* = 3.83$	$p > .05$
Lobb & Davison (1975), conc FI VI	$F(8,8)^* = 0.44$	$p > .05$
conc VI VI	$F(9,9)^* = 2.63$	$p > .05$

Study	*Result*	*Significance*
Marcucella & Margolius (1978)	$F(4,8) = 2.64$	$p > .05$
Matthews & Temple (1979)	$F(4,20) = 0.63$	$p > .05$
McSweeney (1978), 5-sec COD	$F(2,6) = 1.86$	$p > .05$
20-sec COD	$F(3,9) = 0.79$	$p > .05$
Miller (1976), hemp vs. buckwheat	$F(4,12) = 0.74$	$p > .05$
wheat vs. buckwheat	$F(4,12) = 0.96$	$p > .05$
hemp vs. wheat	$F(4,12) = 1.14$	$p > 05$
Miller et al. (1980), 0-degree disparity	$F(5,5) = 1.94$	$p > .05$
15-degree disparity	$F(3,3) = 1.14$	$p > .05$
45-degree disparity	$F(3,3) = 0.44$	$p > .05$
Pliskoff et al. (1978), First Replication	$F(4,8) = 2.34$	$p > .05$
Second Replication	$F(3,6) = 0.84$	$p > .05$
Rider (1979), conc FR MR	$F(3,6) = 1.16$	$p > .05$
Stubbs & Pliskoff (1969), reinforcer proportion varied	$F(3,6) = 1.30$	$p > .05$
Trevett et al. (1972), conc VI VI	$F(3,9) = 0.70$	$p > .05$
Wheatley & Engberg (1978), conc key peck treadle press	$F(10,20) = 1.56$	$p > .05$
Davison & Ferguson (1978)	$F(4,16) = 4.13$	$p < .025$
Davison & Hunter (1976)	$F(26,52)^{*} = 5.28$	$p < .01$
Hollard & Davison (1971)	$F(3,6) = 7.22$	$p < .025$
McSweeney (1978), 0-sec COD	$F(2,6) = 5.22$	$p < .05$
Norman & McSweeney (1978)	$F(3,12) = 3.75$	$p < .05$
Rider (1979), conc FR VR	$F(7,21) = 2.71$	$p < .05$
Trevett et al. (1972), conc FI VI	$F(7,21) = 5.50$	$p < .01$
Wheatley & Engberg (1978), conc key peck treadle press	$F(10,20) = 4.70$	$p < .05$
White & Davison (1973)	$F(11,55) = 7.05$	$p < .01$
Changeover Delay or Changeover Ratio		
Allison & Lloyd (1971), Experiment 1	$F(1,3) = 1.17$	$p > .05$
Experiment 2	$F(9,18) = 1.01$	$p > .05$
Bacotti (1977), conc VI 4-min FR 25	$F(2,6) = 0.54$	$p > .05$
conc VI 4-min FR 50	$F(2,6) = 0.83$	$p > .05$
conc VI 4-min FR 75	$F(2,6) = 0.07$	$p > .05$
conc VI 4-min FR 100	$F(3,6) = 1.48$	$p > .05$
Pliskoff (1971)	$F(18,18)^{*} = 1.43$	$p > .05$
Silberberg & Schrot (1974), Experiment 1	$F(1,3) = 2.97$	$p > .05$
Experiment 2	$F(1,3) = 5.88$	$p > .05$
Stubbs & Pliskoff (1969), COD varied	$F(3,6) = 2.63$	$p > .05$
COR varied	$F(2,4) = 1.20$	$p > .05$
White (1979), Experiment 4	$F(7,7) = 2.01$	$p > .05$
White (1979), Experiment 1	$F(4,12) = 8.17$	$p < .01$
Experiment 2	$F(8,16) = 5.42$	$p < .01$
Deprivation		
Willis et al. (1974)	$F(3,9) = 9.81$	$p < .01$

APPENDIX C

Significant Interactions

Study	*Result*	*Significance*
Local Rates of Reinforcement		
Favorability of Component × Programmed Rate of Reinforcement		
Heyman (1979)	$F(2,6) = 17.90$	$p < .01$
Norman & McSweeney (1978)	$F(3,12) = 4.66$	$p < .025$
Trevett et al. (1972)	$F(3,9) = 5.88$	$p < .025$
Reinforcer × Programmed Rate of Reinforcement		
Hollard & Davison (1971)	$F(3,6) = 8.33$	$p < .025$
Matthews & Temple (1979)	$F(4,20) = 75.84$	$p < .01$
Miller (1976), wheat vs. buckwheat	$F(4,12) = 3.61$	$p < .05$
Favorability × COD or COR		
Stubbs & Pliskoff (1969), COD varied	$F(3,6) = 24.02$	$p < .01$
COR varied	$F(2,4) = 12.36$	$p < .025$
White (1979), Experiment 2	$F(8,16) = 4.04$	$p < .01$
Operanda × Programmed Rates of Reinforcement		
McSweeney (1978), 5-sec COD	$F(2,6) = 6.00$	$p < .05$
20-sec COD	$F(3,9) = 13.65$	$p < .01$
Reinforcer × Deprivation		
Willis et al. (1974)	$F(3,9) = 18.65$	$p < .01$
Schedule × Programmed Rates of Reinforcement		
Trevett et al. (1972), conc FI VI	$F(7,21) = 6.71$	$p < .01$
Rider (1979), conc FR MR	$F(3,6) = 6.64$	$p < .025$
conc FR VR	$F(7,21) = 13.79$	$p < .01$
Local Rates of Responding		
Favorability × Programmed Rates of Reinforcement		
Pliskoff et al. (1978), Second Replication	$F(3,6) = 15.13$	$p < .01$
Reinforcer × Programmed Rates of Reinforcement		
Matthews & Temple (1979)	$F(4,20) = 6.24$	$p < .01$
Miller (1976), hemp vs. buckwheat	$F(4,12) = 4.84$	$p < .025$
Favorability × COR		
Stubbs & Pliskoff (1969)	$F(2,4) = 9.15$	$p < .05$
Reinforcer × Deprivation		
Willis et al. (1974)	$F(3,9) = 19.76$	$p < .01$
Schedule × Programmed Rate of Reinforcement		
Rider (1979), conc FR VR	$F(7,21) = 3.84$	$p < .01$