LEVELS OF AGGREGATION: RELATIVE TIME ALLOCATION IN CONCURRENT-SCHEDULE PERFORMANCE

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The proportion of time allocated to one component of a concurrent variable-interval variable-interval schedule was computed for groups of interchangeover times (aggregates) within several intact time series. Variability in obtained proportions decreased as the number of interchangeover times within each aggregate increased; however, modal proportions failed to correspond to overall relative time allocation computed over the course of an entire experimental session, even at the largest aggregate size. The aggregated time series showed periodicities at small aggregate sizes and general trends in local preference at larger aggregate sizes. It is suggested that overall relative time allocation represents a molar extreme in the aggregation of behavior that may not accurately reflect central tendency in the allocation of time to available alternatives within the context of ongoing behavior.

Key words: concurrent schedules, levels of aggregation, time allocation, matching, key peck, pigeons

Behavior on concurrent schedules is allocated to alternatives in proportion to the consequences of responding on each. This matching relation (Herrnstein, 1961) has been applied to choice in many different situations (see de Villiers, 1977, for a review), assuming the status of a behavioral law. Although there is general agreement that some form of the matching relation adequately describes performance on concurrent schedules (Baum, 1979; Myers & Myers, 1977), there is considerable disagreement concerning the origins of this empirical phenomenon. In the molar view, allocation of choices is determined by large-scale relationships between behavior and its consequences. Responses and reinforcers are aggregated over relatively large periods of time, such as entire experimental sessions, and it is at this

level that relative reinforcement is presumed to control behavior. The molecular view, in contrast, considers these large-scale relations between choice and its consequences to be derived from local properties of the schedules and views matching as a by-product of more fundamental molecular processes. The molar and molecular positions are often viewed as different levels of analysis. However, Nevin (1982) has suggested that because both positions focus upon responses and reinforcers, they should be characterized in terms of "levels of aggregation" rather than levels of analysis. Implicit in both positions is the assumption that controlling variables make contact with responding and operate at particular levels of aggregation. Although the molar and molecular positions may be similar in the data that they use, the behavioral processes invoked by each position are very different. Control by molar relations implies integration and differential weighting of discrete events over relatively long periods of time, whereas control by molecular relations requires moment-to-moment "tracking" of local changes in reinforcement probability (see Shimp, 1969).

A great deal of research and discussion has been devoted to determining the level

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at which concurrent-schedule performance can best be understood (e.g., Nevin, 1982; Shimp, 1982; Silberberg & Ziriaux, 1982). Several attempts to determine whether response allocation on concurrent schedules results from molar or molecular processes have concerned the local structure of behavior. Molar theorists contend that matching in the absence of local structure—for example, sequential dependencies in successive choices (Heyman, 1979; Nevin, 1979)—is evidence of the fundamental nature of molar relations. Proponents of the molecular view have argued that a demonstration of control by local contingencies suggests that molecular relations are more fundamental (Baum, 1981; Hinson & Staddon, 1983a, 1983b; Silberberg & Ziriaux, 1982).

A more moderate view suggests that molar and molecular analyses need not be viewed as incompatible. Several authors (Fetterman & Stubbs, 1982; Nevin, 1982; Shimp, 1982) have suggested that control by molar and molecular contingencies is complementary. One version of this view is that molecular contingencies create local structure in behavior, and molar contingencies determine the allocation of the structured behavior. If it is the case that behavior is controlled on both molecular and molar levels concurrently, then the contribution of the controlling variables at each level can be assessed, and the adequacy with which performance on a particular task can be described in molar or molecular terms can be assessed as well.

This paper investigates the extent to which a molar measure of performance, relative time allocation, describes smaller samples of behavior on concurrent schedules. A common procedure in concurrent-schedule research is to aggregate responses, time, and reinforcers for each alternative over entire experimental sessions. From these data, rates of responding can be computed, expressed as proportions or ratios, and can be compared with reinforcement proportions or ratios. However, in the present analysis, we have obtained detailed recordings of concurrent variable-interval

variable-interval (concurrent VI VI) performance and computed relative time spent on a schedule in behavioral samples of different sizes that we refer to as aggregates. If we define one cycle in a concurrent schedule as a single exposure to both schedules and aggregate size as the number of cycles that are pooled together in analysis, then relative measures can be obtained for samples of time allocation as small as an aggregate size of one (a single cycle) or as large as all of the cycles within an experimental session. When a single relative measure or ratio is calculated for an entire experimental session, time allocation is represented as a single quantity; however, recent evidence (Hinson & Staddon, 1983a, 1983b) suggests that there are regularities in concurrent-schedule performance that this extreme molar approach ignores. By looking at smaller samples of behavior in the present analysis, we should be able to determine the extent to which a single measure computed from data aggregated over the entire session represents ongoing performance described by that same measure. In addition, if relative rate of reinforcement controls time allocation, then there must be some interval over which this control is manifested, or over which some invariance in behavior-reinforcement relationships is apparent. The present analysis should also allow us to determine if there is some level of aggregation, shorter than an entire session, at which there is order in measures of performance that are typically used at molar levels of aggregation.

METHOD

Subjects

Six male White Carneaux pigeons, maintained at 80% of their free-feeding weights, served. All birds had previous exposure to concurrent reinforcement schedules. The pigeons were from two different laboratories: Birds 414, 416, and 417 were from Adelphi University, and Birds 27, 93, and 59 were from the University of Maine. Birds were housed and experiments were conducted at these two universities.

Table 1

Number of sessions per condition and responses, time, reinforcements, and changeovers summed over the last three sessions of each condition.

<i>VI (minutes)</i>		<i>Sessions</i>	<i>Responses</i>		<i>Time (seconds)</i>		<i>COs</i>	<i>Reinforcements</i>	
<i>Red</i>	<i>Green</i>		<i>Red</i>	<i>Green</i>	<i>Red</i>	<i>Green</i>		<i>Red</i>	<i>Green</i>
Bird 27									
2	6	39	12295	3587	11920	3890	2017	134	46
6	2	78	5597	8181	3761	11906	2124	47	133
Bird 93									
2	6	40	19611	9563	10954	5086	2357	135	45
6	2	76	8492	19111	4890	11542	2134	46	134
Bird 59									
2	6	56	3850	1450	10848	4910	2413	135	45
6	2	47	1614	3753	4614	11533	2799	46	134

Apparatus

The data reported here for Birds 414, 416, and 417 were collected in an experiment that has been fully described elsewhere (see Real, 1983). Apparatus, procedures, and sequences of conditions are detailed in that report. The data are from changeover key (CO-key) concurrent VI VI schedules with a brief changeover delay (COD).

Birds 27, 93, and 59 were trained in a sound-attenuated, ventilated chamber providing an experimental enclosure 33 cm high, 34 cm wide, and 30.5 cm deep. Two Gerbrands pigeon keys were mounted symmetrically on the rear of the front wall. The keys were 6.4 cm apart (center to center) and 23 cm above the wire-mesh floor. Keys were transilluminated by Sylvania 28 PSB bulbs with colored caps, 2 bulbs per color. A force of approximately 0.15 N was required to operate the keys and a relay mounted behind the front wall of the chamber produced an audible click each time a key was operated. The opening of the grain magazine was centrally located below the keys and 9 cm above the floor. Masking noise was provided through a speaker in the room housing the chamber. Standard electro-mechanical equipment arranged experimental events and recording from an adjacent room.

Procedure

All birds had prior experience on concurrent VI VI schedules and were placed imme-

diately on the first experimental condition. Birds 27, 93, and 59 were exposed to a slightly modified CO-key procedure in which each response to the yellow left key (CO key) alternated the schedules and the right key (main key) stimuli (red and green), initiated a 1-s COD, and darkened the CO key and made it inoperative. The first peck on the main key following a changeover relit and reactivated the CO key. Main-key responses were reinforced according to the prevailing schedule by 3-s access to mixed grain; sessions were terminated following 60 reinforcements. The birds were initially exposed to concurrent VI 120-s (red) VI 360-s (green) and then shifted to concurrent VI 360-s (red) VI 120-s (green). Each condition was continued at least until overall relative measures showed no consistent daily trends. Intervals for the VI tapes were drawn from an arithmetic progression.

RESULTS

Figure 1 shows relative time allocated to the red component plotted as a function of obtained relative reinforcement frequency, for all conditions for all six subjects. Data are averaged over the last three sessions of each condition. The diagonal drawn from the origin shows the locus of perfect matching. All subjects showed reasonable agreement to matching predictions for relative time allocation. The best fitting regression line describes a linear relationship with a slope of 0.81 and a y intercept of 0.07. Summary

Fig. 1. Relative time allocated to the red component as a function of relative reinforcement frequency for all 6 birds. Data points represent the means of the last three sessions in each condition.

data showing responses, time allocation, changeovers (COs), and reinforcers delivered during terminal performance on each condition are displayed in Table 1 for Birds 27, 93, and 59 and in Table 1 in Real (1983) for Birds 414, 416, and 417.

Aggregate analysis. Relative amount of time allocated to the red component was computed iteratively for groups of interchange-over times (ICTs) within intact time series from experimental sessions. That is, at a given aggregate size, $Tr/(Tr + Tg)$ was computed for all ICTs within the time series. Tr is the sum of ICTs i to $i + n$ in the red component and Tg is the sum of ICTs i to $i + n$ in the green component, where i is the ordinal position of the ICT within the time series for that component and n is one less than the aggregate size. So, at aggregate size 5, for example, relative time in red was computed for ICTs 1 to 5, 2 to 6, 3 to 7, etc. in the time series, and every sixth aggregate was completely nonoverlapping. Relative time in the red component was computed for aggregate sizes ranging from 1 to 40. An aggregate size of 25 ICTs is displayed as a maximum aggregate size because preliminary analyses indicated that the standard deviation of obtained proportions declined to low asymptotic values at an aggregate size of 20 or 25.

Figures 2 and 3 show the relative frequency with which each proportion occurred at the three levels of aggregation shown in the legend. Proportions are represented on the x axis in consecutive class intervals of 0.03. Data are from the last session of each condition for each subject. The most frequently occurring proportion at aggregate size 25 is marked on the x axis by an "a." Overall relative time in the red component is marked by a "b" and is shown in parentheses in the upper left of each panel. In those instances in which both measures fell within the same class interval, that interval is indicated by a "c."

The relative frequency distributions displayed in Figures 2 and 3 show that the variability of relative time allocated to the red component decreased as aggregate size increased. Degree of variability, as reflected in the dispersion of the data points and in the relative height of the modes, was clearly rank-ordered with respect to aggregate size, with the smallest aggregate size showing the greatest degree of dispersion and lowest modal relative frequencies. This was also true for the intermediate aggregate sizes, which were not displayed in order to avoid overcrowding the figures. It is clear that in the majority of cases, relative time allocated to the red component over the course of the experimental session and the modal proportion at aggregate size 25 were not within the same class interval. The distributions were often skewed (e.g., all birds on concurrent VI 120-s [red] VI 60-s [green]—Figure 2; and B-27 and B-59 on concurrent VI 120-s [red] VI 360-s [green]—Figure 3), and in some cases were distinctly bimodal (B-414 on concurrent VI 120-s VI 120-s and on concurrent VI 120-s [red] VI 60-s [green]; and B-417 on concurrent VI 120-s VI 120-s—Figure 2). The presence of or direction of skew in the relative frequency distributions was not systematic with respect to subject or reinforcement frequency. Further, those cases in which the most frequently occurring proportion and the session summary statistic fell within the same class interval were no more or less likely to be from subjects or

CLASS INTERVAL (rel time in red)

Fig. 2. Proportion of time allocated to the red component for the three aggregate sizes shown in the legend. Proportions are represented in 30 consecutive 0.03-class intervals; relative frequency of each proportion is represented on the ordinate. Data are from the last session of each condition for Birds 414, 416, and 417. Individual subjects are shown in columns. See text for additional details.

Fig. 3. Proportion of time allocated to the red component for the three aggregate sizes shown in the legend. Data are from the last session of both conditions for Birds 27, 93, and 59.

reinforcement frequencies showing close approximation to matching predictions (cf. Figure 1). There was close agreement between overall relative time allocated to the red component within these sessions, shown in parentheses, and the data displayed in Figure 1, even though the data in Figure 1 were derived from independent run-time counters and represent the means of three sessions.

Figures 4 through 9 show the first 100 aggregates in the time series at aggregate size 5 (filled circles) and 25 (unfilled circles) for the last session of each condition for all birds. The unfilled triangles show the aggregates of size 25 within which local rate of reinforcement, computed as the number of reinforcers within an aggregate divided by the amount of time within an aggregate, was higher in the red component than in the green component. Relative time allocated to the red component over the course of the whole session is shown by the horizontal dashed line. The

proportion of a session represented by the 100 aggregates shown depends on the number of cycles per session. This number, which can be obtained by halving the number of COs per session, ranged from 130 to 344 for Birds 414, 416, and 417, and from 336 to 427 for Birds 27, 93, and 59.

There are several important aspects of these figures. First, there was a general smoothing of the time series as aggregate size increased from 5 to 25. This corresponds to the sharpening of the relative frequency distributions shown in Figures 2 and 3. Second, smoothing of the time series at aggregate size 25 notwithstanding, there were substantial deviations from relative time allocated to the red component over the entire session within many of the aggregated time series. Although there was individual variation in the pattern of time allocation, in half of the cases shown, subjects allocated more time to the red component at the beginning of the session than would be pre-

Fig. 4. Relative time allocated to the red component in the first 100 aggregates, at aggregate size 5 (filled circles) and size 25 (unfilled circles). The unfilled triangles represent aggregates of size 25 in which local reinforcement rate was higher in the red component than in the green component. Data are from the last session of concurrent VI 120-s VI 120-s for all 3 subjects. The horizontal dashed line shows overall relative time in red.

dicted by the summary statistics. In fact, there were only three instances in which subjects showed close approximation to session statistics early in the session and throughout the 100 aggregates (B-417 on concurrent VI 120-s [red] VI 60-s [green]—Figure 5; B-416 on concurrent VI 60-s [red] VI 120-s [green]—Figure 7; and B-27 on concurrent VI 360-s [red] VI 120-s [green]—Figure 9). When deviations from session statistics occurred early in the session, the trends in the aggregated

time series suggest a systematic drift in local relative time allocation in the direction of the summary statistics. For example, on concurrent VI 120-s VI 120-s (Figure 4), all subjects allocated less time to the red component at the beginning of the session than would be predicted and showed gradual increases in the proportion of time in red over the course of the 100 aggregates. However, B-414 and B-417 showed increases in excess of the session summary statistic. On concurrent VI

Fig. 5. Relative time allocated to red during the last session of concurrent VI 120-s (red) VI 60-s (green). Details as in Figure 4.

80-s VI 80-s (Figure 6), all birds allocated more time to the red component than would be predicted on the basis of session statistics, as did B-59 on concurrent VI 360-s (red) VI 120-s (green) shown in Figure 9, and then showed a gradual decrease in the proportion of time allocated to red. All birds on concurrent VI 80-s VI 80-s showed additional decreases in proportion of time in red to below the session summary statistics. In other cases, the deviation from session statistics was of a more phasic nature, showing increases and decreases over the course of the 100 aggregates (e.g., B-416 on concurrent VI 120-s [red] VI 60-s [green]—Figure 5; B-417 on concurrent VI 60-s [red] VI 120-s [green]—Figure 7; B-93 and B-59 on concurrent VI 120-s [red] VI 360-s [green]—

Figure 8; and B-93 on concurrent VI 360-s [red] VI 120-s [green]—Figure 9).

In most of the cases shown, the aggregates in which local reinforcement rate in the red component was higher than that in the green component were grouped in blocks of 15 or more consecutive aggregates, regardless of absolute or relative reinforcement frequencies. In several cases, increases in relative time allocated to the red component appeared to lag behind blocks of aggregates in which local reinforcement rate in red was higher than in green (e.g., B-414 on concurrent VI 120-s VI 120-s—Figure 4; B-417 on concurrent VI 60-s [red] VI 120-s [green]—Figure 7; B-93 on concurrent VI 360-s [red] VI 120-s [green]—Figure 9). However, in most blocks of aggregates in which local rate

Fig. 6. Relative time allocated to red during the last session of concurrent VI 80-s VI 80-s. Details as in Figure 4.

of reinforcement in the red component was higher, relative time allocated to the red component either decreased across successive aggregates (e.g., B-414 on concurrent VI 120-s [red] VI 60-s [green]—Figure 5; B-416 on concurrent VI 80-s VI 80-s—Figure 6; B-59 on concurrent VI 120-s [red] VI 360-s [green]—Figure 8) or was unrelated to any trends in local rate of reinforcement across aggregates (B-27 on concurrent VI 360-s [red] VI 120-s [green]—Figure 9).

At aggregate size 5, relative time allocation across aggregates was substantially more variable. In addition, there was evidence of locally shifting preference across aggregates. These changes follow the more

gradual trends evident at aggregate size 25. The shifts in preference were only occasionally abrupt, as would be expected given the intrusion of ICTs of very discrepant durations into the computation and, by visual inspection, appear to show a periodicity of 10 to 12 aggregates. In some cases this periodicity is markedly regular, as in the case of B-417 on concurrent VI 120-s VI 120-s (Figure 4), B-416 and B-417 on concurrent VI 80-s VI 80-s (Figure 6), and B-93 and B-59 on concurrent VI 360-s (red) VI 120-s (green) in the last half of the 100 aggregates (Figure 9).

The long-term and short-term trends in relative time allocation shown in Figures 4

Fig. 7. Relative time allocated to red during the last session of concurrent VI 60-s (red) VI 120-s (green). Details as in Figure 4.

through 9 were not restricted to those portions of the sessions displayed. Similar trends were evident in the remainder of those sessions shown and in other sessions of each condition.

Figures 10 and 11 show the first 100 ICTs in both components from representative sessions displayed as aggregated time series in Figures 5 through 7. The appearance of the aggregated time series reflects trends in local time allocation in both components, so that point-for-point comparison of the figures is difficult. However, groups of 5 to 6 ICTs

that showed ascending and descending trends are evident, particularly in the last half of the time series from the red component during the final session of concurrent VI 60-s (red) VI 120-s (green) for B-416 (Figure 10) and in the last half of the time series from the green component during the final session of concurrent VI 120-s (red) VI 60-s (green) for B-414 (Figure 11). It is clear that the ICTs in the preferred of an asymmetrical pair of schedules were more variable than in the unpreferred component. It is likely, then, that cyclicities in the aggre-

Fig. 8. Relative time allocated to red during the last session of concurrent VI 120-s (red) VI 360-s (green). Details as in Figure 4.

gated time series at aggregate size 5 were due primarily to local trends in the preferred of the asymmetrical pairs. In addition, occasional abrupt shifts in preference in the aggregated time series can be traced to discrepantly long ICTs in the intact time series. For example, in the middle of the time series from the red component during the last session of concurrent VI 120-s (red) VI 60-s (green) for B-414 (Figure 10), there was a cluster of long ICTs that appeared as a fairly prolonged shift toward a red preference in the aggregated time series for this session (Figure 5). Similarly, the very long ICT at the beginning of the time series from the red component during the final session of con-

current VI 80-s VI 80-s for B-416 appeared as an abrupt, but transient, shift toward a red preference at the beginning of the aggregated time series (Figure 6).

In Figure 12, the proportion of aggregates in which local reinforcement rate in a component was zero is plotted as a function of aggregate size for all 6 birds on all conditions. Each panel shows the average proportion for 3 birds. Filled triangles represent the green component and filled circles represent the red component when schedules were asymmetrical, or the average of both components when schedules were symmetrical. The vertical bars show the range of proportions across subjects. These data were taken

Fig. 9. Relative time allocated to red during the last session of concurrent VI 360-s (red) VI 120-s (green). Details as in Figure 4.

from the last session of each condition.

In both concurrent-schedule components, the proportion of aggregates with a local reinforcement rate of zero decreased as aggregate size increased. This result was consistent across birds and conditions. When component schedules were asymmetrical, the proportion of aggregates with zero local reinforcement rate was consistently lower in the schedule providing a higher absolute reinforcement rate; however, exposures to a particular reinforcement frequency produced curves that were highly similar regardless of relative reinforcement rates and despite differences in CO rates (see Table 1; see also Table 1 in Real, 1983). Compare all exposures to VI 120-s, for an example. As the disparity between component schedules increased, the difference in the proportion of

aggregates with zero local reinforcement rate also increased across components and produced greater separation of the curves. Finally, at each aggregate size, the proportion of aggregates with zero local reinforcement rate increased as programmed reinforcement rate decreased.

DISCUSSION

In the present analysis, a molar measure of concurrent-schedule performance, relative time allocated to the alternatives, was examined at different levels of aggregation. Relative time allocation computed over the entire session, though systematically related to reinforcement frequency at this particular level of aggregation, failed to describe performance over smaller samples of behavior

Fig. 10. The first 100 ICTs in the red component from selected final sessions that are represented as aggregated time series in Figures 5 through 7. ICTs are displayed in consecutive ordinal position.

or at all times within an experimental session. Similar results were obtained with birds from different laboratories and at different absolute reinforcement rates. Variability in relative time allocation across successive aggregates decreased as aggregate size increased, but even at an aggregate size of 25 there were substantial deviations from relative time computed over the entire session within most of the aggregated time series. As aggregate size was increased in these analyses, the addition of the next exposure to the two schedules comprised a smaller and smaller portion of the data in each aggregate. This characteristic of the iterative analysis presented here lessens the contribution of any given exposure to the two schedules. Thus, as aggregate size becomes large, increasingly discrepant data points would be required to shift relative time allocation within an aggregate widely in either direction. Decreases in variability were, therefore, to be expected, but the failure of the modal proportions at aggregate size 25 to correspond to relative time computed for the session was unexpected. This latter finding was particularly surprising because prelim-

Fig. 11. The first 100 ICTs in the green component from selected final sessions represented as aggregated time series in Figure 5 through 7. Details as in Figure 10.

inary tests showed that the standard deviation of obtained proportions, in both independent and iterative analyses, approached asymptotically low levels at aggregate sizes 20 and 25.

It is clear that overall relative time allocation was not well described by its constituents at the levels of aggregation used in the present study. The bimodal distributions in Figure 2 are extreme examples in which subjects allocated time to alternatives in one of two different ways, neither of which was represented in the session statistic. One could conceive of many ways in which this could be true, in addition to the skewness in the distribution of proportions reported here. Furthermore, the present study found that most subjects, in most conditions, showed substantial deviations from session statistics at the beginning of an experimental session and then showed compensatory changes in relative time allocation. This result suggests the possibility that the adequacy of matching as a description of performance, computed on the basis of overall relative time allocation, may depend critically on the interval of time over which behavior is free to vary. It is conceivable that there are session durations that favor matching as a molar result, and others that do not.

The present account does not explicitly

Fig. 12. The proportion of aggregates in which local reinforcement rate was zero as a function of aggregate size for all subjects in all conditions. Triangles represent proportions in the green component; circles represent proportions in the red component when schedules were asymmetrical or both components when schedules were symmetrical. Data points represent the average, across birds, of the final session in each condition. The range across birds is shown by the vertical bars.

address relative time allocation, as a component of the matching relation, as anything other than a measure of central tendency. The matching relation clearly predicts that relative behavioral output is controlled by relative distribution of reinforcement, but is silent regarding processes that might be said to underlie the relation between reinforcer distribution and behavior. As Staddon (1980) pointed out, nonspecification of such behavioral processes is characteristic of molar theories. In addition, the matching relation does not specify the time frame over which control by reinforcer distribution is manifested. Matching implies that relative reinforcement rate, as a controlling variable, operates over a relatively long period of time. However, some molar theorists view

the pigeon's time frame as relatively short (see Baum, 1973; Rachlin, 1982). The molar view is thus left without two vital pieces of information: behavioral processes that might produce matching and a time frame over which control by relative reinforcement rate is manifested. Information about either one of these would facilitate identification of the other.

Herrnstein (1982) and others (Herrnstein & Vaughan, 1980; Vaughan, 1981) have suggested that a mechanism of behavioral change is required by matching. They have proposed a mechanism called melioration, which involves shifts in preference toward higher local rates of reinforcement and results in matching at equilibrium. Melioration is a molar process, involving the aggregation of reinforcers over time, but the local

rates of reinforcement are presumable effective over smaller samples of behavior than those over which the matching relation is applied.

Vaughan (1981) demonstrated that pigeons behaved in ways that are compatible with melioration when local rates of reinforcement in successive 4-min intervals were dependent on relative time allocation in the preceding 4-min interval. Two procedural variations in his experiment are particularly noteworthy: First, VI tapes advanced only while a subject responded; and second, while a subject responded on one alternative, the other VI tape stopped. His procedure is, therefore, much more analogous to a concurrent VR VR than to a concurrent VI VI. The present data suggest that there is change in local time allocation even when there is no explicitly programmed contingency relating samples of relative time allocation to reinforcement rate, as in Vaughan's study. An interaction between these two variables is implied both by the mechanism of melioration as it has been articulated and by the details of Vaughan's study. A sensitivity to changes in local reinforcement rate that occur independently of or are produced by changes in local time allocation is a minimum prerequisite for a process such as melioration; however, little else is implied or stated explicitly by the proponents of melioration. The interval of time over which melioration might occur is unspecified, the time frame over which an animal "tracks" changes in local reinforcement rate is unspecified, and a formal definition of equilibrium within or between sessions is lacking.

It is difficult to define, for a concurrent VI VI, a state in which local rates of reinforcement are stable or in which the difference between local reinforcement rates across components is stable. We have presented data suggesting that local reinforcement rate is often, at least transiently, higher in the locally or globally unpreferred component. This result is forced, to some extent, because local reinforcement rate, when nonzero, varies inversely with local time allocation.

Furthermore, the variability in local reinforcement rate, across samples of behavior, appears to depend critically on the level of aggregation used. For example, at an extreme molecular level, Menlove (1975) and Real (1983) have shown that rate of reinforcement as a function of time since an immediately preceding changeover can be affected by procedural variations such as the presence of a changeover delay, and that local reinforcement rates decline monotonically as a function of time since a changeover. At another extreme, Rachlin, Green, Kagel, and Battalio (1976) have shown in a computer simulation that local rate of reinforcement, computed on the basis of time allocated to each component within a session, may be virtually invariant when time allocation on the least preferred of an asymmetrical pair of schedules is varied over a wide range. The present results suggest that at intermediate levels of aggregation, variability in local reinforcement rate declines monotonically as a function of aggregate size, as does the variability in local relative time allocation. Thus, the task of "meliorating" becomes increasingly difficult as an animal's time frame becomes smaller, because the variability in obtained feedback should shift local preferences widely. Melioration becomes undetectably different from matching as a behavioral process (or what Hinson & Staddon [1983a, 1983b] refer to as a molar comparison strategy) as an animal's time frame approximates the length of an experimental session or spans several sessions. Further, we found no strong evidence that time allocation, at aggregate size 25, was determined by locally higher reinforcement rates.

One purpose of molecular analyses of concurrent-schedule performance is to ascertain the local contingencies that determine the allocation of aggregate responding (see Hinson & Staddon, 1983b). If there is a process by which reinforcement rate determines time allocation, it is reasonable to assume that it operates at the level at which variability, in both local reinforcement rate and local relative time allocation, approaches

asymptotically low levels. The present analyses suggest that this low asymptote is approximated at an aggregate size of 25, using the proportion of aggregates within which local reinforcement rate is zero as an index of variability. We have suggested that the contingencies that operate at this particular level of aggregation are unlikely to be those of melioration, which could involve more subtle discriminations than zero versus non-zero. However, we have shown that the functions relating the proportion of aggregates with zero reinforcement rate to aggregate size are orderly and consistent across subjects, conditions, and different relative reinforcement rates. It is likely, therefore, that these functions represent a consistent relationship between behavior and reinforcement on concurrent VI VI schedules that is maintained across disparate average ICTs (see Table 1; see also Table 1 in Real, 1983). These results suggest that it would be fruitful to seek the contingencies that determine relative time allocation at levels identified by functions such as these, because it is unclear from the present account whether these functions represent a dynamic property of the behavior-reinforcement relationship. It should be clear from the present analyses and from earlier accounts of concurrent schedule performance that the orderly relationships that emerge from an analysis of reinforcement rate and time allocation depend substantially on the measures used and the level of aggregation to which those measures are applied.

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