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VARIABLE-INTERVAL SCHEDULE PERFORMANCE IN OPEN AND CLOSED ECONOMIES

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In two experiments, pigeons obtained food according to variable-interval schedules. In the first experiment, equivalent variable-interval schedules with average interreinforcer intervals ranging between 10 and 80 s in different conditions were studied in both open and closed economies. Response rates increased as reinforcement frequency decreased in the closed economy. By contrast, in the open economy response rates decreased for 1 bird and were variable for the other as reinforcement frequency decreased. The second experiment showed that the differences in the functions between responding and reinforcement frequency in the two types of economies were not due to changes in deprivation level. These results suggest that open and closed economies yield different behavioral effects. This conclusion is supported further by a reconsideration of previous findings that appear counter to the conclusion.

Key words: open economy, closed economy, variable-interval schedules, behavioral economics, behavior regulation, key peck, pigeons

Recent studies have yielded conflicting accounts of the behavioral effects of open and closed economies. Hursh defined a closed economy as "an ideal state when daily consumption is the result of the equilibrium of supply and demand" (1980, p. 223). In other words, total daily consumption is determined solely by an organism's interaction with the reinforcement schedule(s). By contrast, an open economy includes "any of a variety of experimental arrangements that provides at least a measure of independence between daily responding and the equilibrium condition" (Hursh, 1984, p. 223). For example, an animal's body weight might be held constant at 80% of free-feeding weight either by supplemental feeding or by providing a fixed number of food presentations during each session.

According to an economic perspective (Hursh, 1978, 1980, 1984), the type of economy is an independent variable that produces different behavioral effects. Hursh (1978) studied complex concurrent variable-interval (VI) schedules for food and water in open and closed economies using rhesus monkeys as subjects. In the closed economy, lengthening the interfood interval on one of two concurrent VI food schedules increased responding for food. In the open economy, lengthening the average interreinforcer interval arguably decreased food responding. Catania and Reynolds (1968) studied simple VI food schedules in open economies using pigeons as subjects. As the interreinforcer interval was lengthened, response rates decreased slightly. Collier, Hirsch, and Hamlin (1972) studied fixed-ratio (FR) food schedule performance of rats in closed economies. As the ratio requirements increased, response rates increased. There was a slight decrease in responding, however, at the highest ratio requirement. Felton and Lyon (1966) studied FR food schedules with pigeons in an open economy. With the first two increasing ratio requirements, response rates increased. As the ratio requirements increased further, however, responding decreased. On the basis of these studies, Hursh (1978, 1980, 1984) concluded that closed economies yield a primarily inverse relation between response rates and reinforcer frequency with both VI and FR schedules, whereas open economies yield a primarily direct relation.

Other researchers have challenged the notion that open and closed economies produce different behavioral effects. According to the behavior regulation view of Timberlake and Peden, "it should be possible to produce both direct and inverse relations in both open and closed economies simply by manipulating the reward density" (1987, p. 37). Reward density is a ratio of the percentage of baseline hopper access time to the schedule value, or cost. For

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example, if the hopper access time is 1% of baseline and the schedule value is VI 20 s, reward density equals 1/20 or .05. Different reward densities may be produced by varying hopper access time, schedule value, or both. Timberlake and Peden studied the relation between pigeons' response rates and reward density in open and closed economies, using both FR and VI food schedules. Within a mid-range of reward densities in the closed economy, increasing reward density decreased food responding. Within a range of low reward densities in the closed economy, increasing reward density slightly increased, then decreased, responding in 3 of 4 subjects. Within a range of low reward densities in the open economy, increasing reward density led to variable responding in all 4 subjects and arguably increased, then decreased, responding in 3 of 4 subjects. On the basis of these findings, Timberlake and Peden concluded that open and closed economies yield a single bitonic relation between response rates and reward density. A bitonic relation is one that includes both direct and inverse relations between responding and reward density.

Timberlake and Peden (1987) suggested that findings from prior economic research are not incompatible with a behavior regulation perspective. In a review of the literature, Timberlake and Peden found "only one set of experiments in which subjects' responding was examined under the same schedules of reinforcement over similar reward densities in both types of economy . . . Hursh's (1978) original work with . . . monkeys" (1987, p. 51). According to Timberlake and Peden, Hursh's data may not demonstrate that open and closed economies produce opposite functions because the shape of Hursh's open economy function depended on a single data point. If that point were removed, they noted that the open-economy function would not show the predicted direct relationship between responding and reward density. In addition, Timberlake and Peden suggested that "the remaining differences in responding between open and closed economies in Hursh's (1978) data may be due to differences in deprivation. When tested under the open-economy procedures, the monkeys had lower body weights . . . than when tested using closed-economy procedures" (p. 52).

On the other hand, Timberlake and Peden's (1987) findings may not demonstrate conclusively that open and closed economies yield the same behavioral effects and that the shape of the relation between response rates and reward density is bitonic. Although Timberlake and Peden did not obtain opposite relations between response rates and reward density (as would be predicted by an economic view), the functions differed in certain respects. In general, the closed-economy functions in Experiments 1 and 2 were more controlled, well defined, and steeper than the open-economy functions in Experiment 4. In terms of procedures, Timberlake and Peden used different subjects in the two types of economy; there was no direct within-subject comparison of economic effects. In addition, economic effects were compared only across a range of low reward densities (Experiments 2 and 4). Given that Timberlake and Peden obtained similar results to Hursh (1978) in a closed economy using a mid-range of reward densities (Experiment 1), it would have been desirable to test the same mid-range in an open economy.

Thus, previous research has not established whether different types of economies yield different behavioral effects. The present study provided an intrasubject comparison of the effects of open and closed economies across an identical mid-range of VI schedule values. Single food reinforcement schedules were used rather than the complex concurrent food and water schedules used by Hursh (1978). In addition, the contribution of deprivation level to the effects of open and closed economies was assessed.

EXPERIMENT 1

The first experiment examined the effects of variable-interval schedules with different interreinforcer intervals on response rate and percentage body weight in closed and open economies.

METHOD

Subjects

The subjects were 2 male White Carneau pigeons with experience under a variety of schedules. Their body weights varied from 79% to 101% of free-feeding weights, depending on the condition. Water and Palmetto health grit were available continuously in the home cages.

Apparatus

The experiment was conducted in an operant conditioning chamber for pigeons with internal dimensions of 30.5 cm long by 32.5 cm wide by 38 cm high. The 2.0-cm-diameter response key was located on the work panel 8.5 cm from the right wall and 25.5 cm from the floor of the chamber. It was transilluminated by a 28-V DC bulb at all times except during the delivery of reinforcers. A force of at least 0.15 N was required to operate the key. General illumination of the chamber was provided by a white 28-V DC bulb. Reinforcers consisted of 3-s access to mixed pigeon grain in a standard food magazine, the opening to which was on the center of the work panel, 10.5 cm from the floor. The opening was illuminated by a white 28-V DC bulb during magazine operation. Experimental conditions were controlled from an adjacent room by a PDP 8/a® minicomputer using SuperSKED® software.

Table 1

Sequence of conditions, number of sessions, and session duration for Birds 2923 and 5511 in Experiment 1.

	Number of sessions	Schedule and economy type	Session duration
Bird 2923	13	VI 20 s closed	1 hr
	34	VI 40 s closed	1 hr
	19	VI 60 s closed	1 hr
	34	VI 20 s closed	1 hr
	19	VI 80 s closed	1 hr
	22	VI 80 s open	1 hr
	27	VI 20 s open	15 min
	14	VI 40 s open	30 min
	19	VI 60 s open	45 min
Bird 5511	42	VI 10 s closed	1 hr
	10	VI 20 s closed	1 hr
	15	VI 40 s closed	1 hr
	14	VI 10 s closed	1 hr
	17	VI 60 s closed	1 hr
	18	VI 60 s open	1 hr
	41	VI 10 s open	10 min
	21	VI 20 s open	20 min
	22	VI 40 s open	40 min

Procedure

Four VI schedules were studied in closed and open economies. In the closed economy, each bird's total daily intake of food was determined by its interaction with the reinforcement schedule in effect during a 1-hr session. In the open economy, total daily intake was held constant by the experimenter. Regardless of its performance during the session, Bird 2923 received 18 g of food per day and Bird 5511 received 22 g. Whatever proportion of this total daily intake was not obtained in the session was provided by supplemental feeding in the home cage immediately after the session. The amount of food provided by the different VI schedules in the different conditions also was held constant by varying session length from 10 to 60 min.

The sequence of conditions, corresponding number of sessions, and session duration for each subject are shown in Table 1. Bird 5511 consistently responded at higher body weights than did Bird 2923. Thus, the VI intervals for Bird 5511 were consistently shorter than for Bird 2923. Each VI schedule was defined by a Fleshler and Hoffman (1962) progression of 25 intervals, and each interval was selected randomly without replacement.

Each condition was in effect for at least 10 sessions and was changed when the data appeared stable on visual inspection. Sessions were conducted 7 days per week.

Results

The upper portion of each graph in Figure 1 shows the response rates of Birds 5511 and 2923 for the last 10 sessions of each condition. Response rates were calculated by dividing the total number of pecks by the length of the session, excluding reinforcement time. The lower portion of each graph in Figure 1 shows percentage body weight of each bird for the same sessions. In the closed economy, response rates for both birds increased as the average interreinforcer interval was lengthened. With Bird 5511, the greatest response rate increase occurred when the average interreinforcer interval was lengthened from VI 10 s to VI 20 s. Increases were somewhat less pronounced when the schedule was changed from VI 20 s to VI 40 s and from VI 40 s to VI 60 s. Bird 2923 showed a similar pattern of responding. When the schedule was changed from VI 20 s to VI 40 s, a relatively large increase in responding was found. Following a change from VI 40 s to VI 60 s and from VI 60 s to VI 80 s, more modest increases in responding occurred.

In the closed economy, percentage body weight for both birds remained the same or

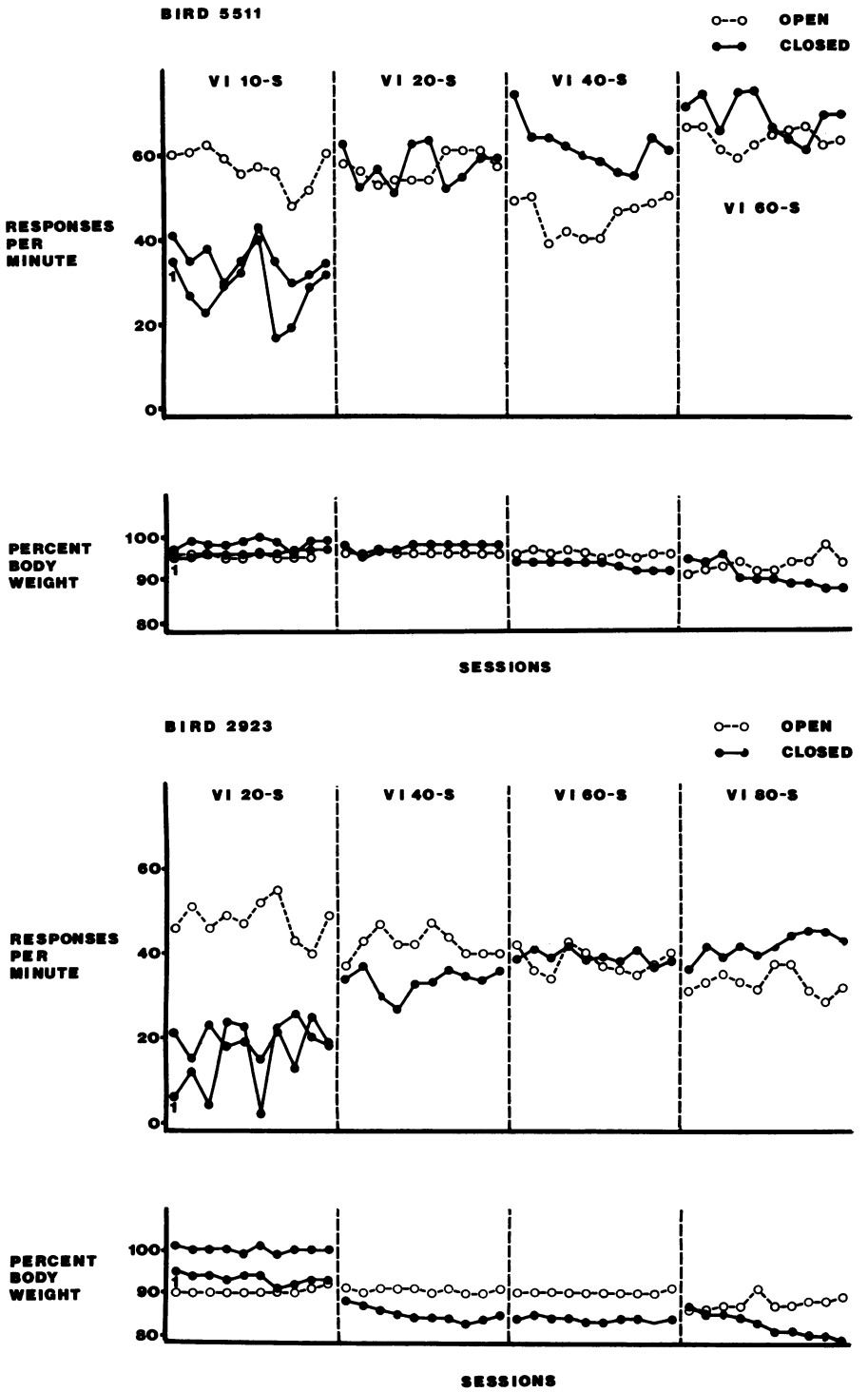

Fig. 1. Response rates (upper portion) and percentage body weights (lower portion) of Birds 2923 and 5511 for the last 10 sessions of each condition in Experiment 1. Open and closed circles depict data obtained from open and closed economies, respectively.

decreased as the average interreinforcer interval was lengthened. Nevertheless, relations between percentage body weight and response rates were inconsistent. With Bird 5511, percentage body weight remained approximately the same when the interval increased from VI 10 s to VI 20 s, but response rates increased dramatically across the same schedule parameters. By contrast, percentage body weight for Bird 5511 dropped slightly when the schedule was changed from VI 20 s to VI 40 s and from VI 40 s to VI 60 s, whereas response rates increased slightly across the same values. With Bird 2923, percentage body weight decreased as the schedule was changed from VI 20 s to VI 40 s, and response rates increased across the same values. As the schedules were changed from VI 40 s to VI 60 s and from VI 60 s to VI 80 s, percentage body weight for Bird 2923 dropped slightly and responding increased slightly.

In the open economy, response rates for Bird 2923 decreased slightly, but consistently, as the average interreinforcer interval was lengthened. With Bird 5511, responding remained approximately the same as the schedule was changed from VI 10 s to VI 20 s, then decreased when the schedule was changed to VI 40 s. When the schedule was changed from VI 40 s to VI 60 s, responding increased.

In the open economy, percentage body weight for both birds remained stable across VI 10-s, VI 20-s, and VI 40-s conditions (Bird 5511) and across VI 20-s, VI 40-s, and VI 60-s conditions (Bird 2923). With VI 60 s (Bird 5511), the first six data points in Figure 1 reflect slightly lower percentage body weights than those in the other conditions. With VI 80 s (Bird 2923), 8 of the 10 data points also reflect a slightly lower body weight. Because responding for both birds varied across different schedule parameters despite stable body weights, responding generally was not a systematic function of body weight.

Comparisons at the same VI value across the two types of economy shed additional light on the relation between response rates and body weight. In the VI 20-s condition, Bird 2923's body weight was higher but it responded at lower rates under the closed than the open economy. In the VI 40-s condition, however, Bird 2923 showed opposite effects. In the VI 60-s condition, percentage body weight was higher in the open economy, yet response rates were the same in both open and closed economies. In the VI 80-s condition, percentage body weight again was higher in the open economy and response rates were lower in the open economy. With Bird 5511 in the VI 10-s, 20-s, and 60-s conditions, percentage body weights were similar under both types of economy, but response rates were lower in the closed economy. In the VI 40-s condition, Bird 5511's body weight was slightly higher and responding was substantially lower in the open economy.

Table 2

Response rates for Birds 2923 and 5511 during a period defined by the first 30 reinforcers of each session. Each data point represents the mean of the last three sessions in each condition.

	Schedule and economy type	Response rate
Bird 2923	VI 20 s closed	21.77
	VI 60 s closed	37.5
	VI 80 s closed	43.3
	VI 80 s open	30.77
	VI 20 s open	43.83
	VI 40 s open	42.77
	VI 60 s open	36.6
Bird 5511	VI 10 s closed	71.07
	VI 20 s closed	79.33
	VI 40 s closed	57.67
	VI 60 s closed	66.23
	VI 60 s open	63.57
	VI 10 s open	56.63
	VI 20 s open	58.67
	VI 40 s open	51.53

Table 2 shows the response rates of Birds 5511 and 2923 during the portion of each session in which the first 30 reinforcers were presented. Each data point represents the mean of the last three sessions of each condition, excluding VI 40 s for Bird 2923 (within-session data from this latter condition were unavailable). With Bird 2923, response rates during the early portion of the session were nearly identical to those for the entire session. In the closed economy, response rates increased as the average interreinforcer interval was lengthened; an opposite functional relation was obtained in the open economy. With Bird 5511, response rates during the early portion of each session were similar to those for the entire session for all conditions of the open economy and the VI 40-s and VI 60-s conditions of the closed economy. Response rates for the early

portion of the session were higher than those for the entire session in the VI 10-s and VI 20-s conditions of the closed economy, and responding was higher in the VI 20-s condition than in the VI 10-s condition.

EXPERIMENT 2

Timberlake and Peden (1987) suggested that the apparent differences in effects between open and closed economies may be due to differences in deprivation level or body weight rather than to differences in the defining features of the economies. Although the results of the first experiment suggested no systematic relation between body weight and economy, body weights in the two types of economy differed at the same schedule values. The second experiment directly assessed a possible relation between body weight and responding within open and closed economies.

METHOD

Subjects and Apparatus

Both birds from the first experiment served as subjects. The apparatus was that used in the first experiment.

Procedure

Following the final condition of the first experiment, both subjects were exposed to two additional VI schedule values in an open economy. Under these new conditions, the birds' weights were matched as closely as possible, on a session-by-session basis, with weights they had attained under the same schedule parameters in the closed economy in the first experiment. Bird 2923 was exposed to VI 40 s (21 sessions, 20 min in duration each) and VI 80 s (19 sessions, 45 min each) and Bird 5511 was exposed to VI 10 s (14 sessions, 10 min each) and VI 60 s (22 sessions, 50 min each). These VI values were chosen because they produced differences in response rates between the two economies in Experiment 1. With Bird 2923, VI 40 s was chosen as a low value (rather than VI 20 s) because it appeared more likely to produce consistent responding in Experiment 2. In most cases, matching weights required session durations to be shortened slightly from the durations in Experiment 1. Otherwise, subjects would have obtained too much food in each session to attain the desired matched weights. All other procedures in Experiment 2 were as in Experiment 1.

RESULTS

The upper portion of each graph in Figure 2 shows response rates of Birds 5511 and 2923 for the last 10 sessions of each condition under open and closed economies. The lower portion of each graph in Figure 2 shows percentage body weight of each bird for the same sessions. In the closed economy, response rates for each bird increased and body weights decreased as the average interreinforcer interval was lengthened. The increase in responding for Bird 5511 was more pronounced than the increase for Bird 2923. In the open economy, response rates remained the same (Bird 2923) or decreased slightly (Bird 5511) as the VI schedule was changed. Body weights decreased, as in the closed economy. Neither bird's data showed a systematic relation between body weight and response rates that was independent of the type of economy.

DISCUSSION

The present results support a distinction between the behavioral effects of open and closed economies. They extend earlier work in that pigeons were exposed sequentially to both open and closed economies in which single food reinforcement schedules were in effect and deprivation level was monitored (Experiment 1) or controlled (Experiment 2). Open and closed economies yielded different functional relations across an identical mid-range of VI schedule values. According to Timberlake and Peden, "... in a behavior-regulation view, a likely basis for reported differences in response–reward relations in open and closed economies is differences in reward density" (1987, p. 37). The present results do not support this explanation, because the same VI schedule values and hopper durations (reward densities) were used in open and closed economies and different functional relations were obtained.

Differences in the behavioral effects of open and closed economies cannot be explained solely by differences in deprivation level. When body weights in an open economy were matched to weights obtained in a closed economy (Experiment 2), different functional relations between response rates and VI reinforcer fre-

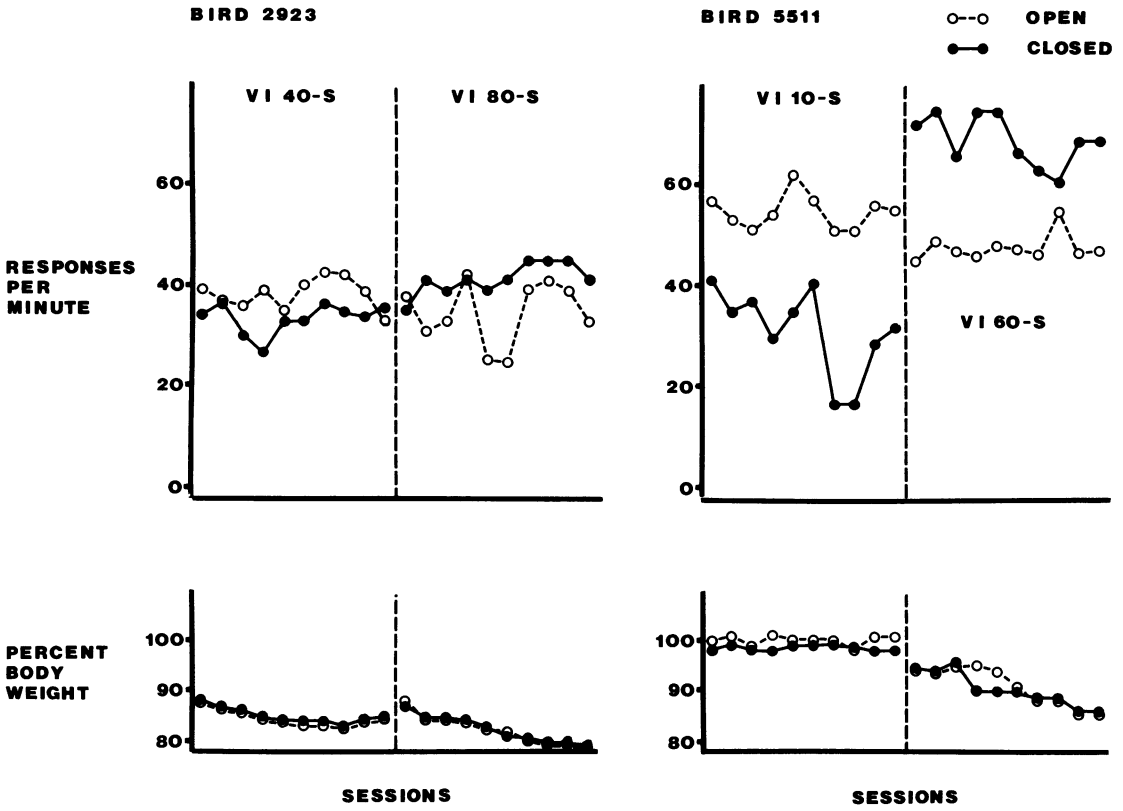

Fig. 2. Response rates (upper portion) and percentage body weights (lower portion) of Birds 2923 and 5511 for the last 10 sessions of each condition in Experiment 2. Open and closed circles depict data obtained from open and closed economies, respectively.

quency still were obtained. These effects were more pronounced with Bird 5511 than Bird 2923, but the same trends were observed in the behavior of both birds. Differences in the effects of open and closed economies also do not seem reducible to factors such as differences in session length and reward density across different types of economy. In the VI 60-s condition for Bird 5511, responding in open and closed economies differed markedly despite approximately the same session length and reward density. With these factors ruled out, the only difference between open and closed economies in the VI 60-s condition appears to be the extent to which total daily intake is contingent on within-session performance. As mentioned previously, the open economy "provides at least a measure of independence between daily responding and the equilibrium condition" (Hursh, 1984, p. 223), whereas the closed economy does not.

The behavior-regulation view that the functional relations in both open and closed economies are bitonic was not supported by these data. Nevertheless, the present functions might show bitonicity if extended over a wider range of VI values. Hursh (1980) identified bitonic effects in the studies by Felton and Lyon (1966) and Collier et al. (1972). In these studies, bitonicity resulted from the inclusion of relatively high FR values (low reward densities) in the closed economy and relatively low FR values (high reward densities) in the open economy. Across a mid-range of FR values, however, Collier et al. (1972) found that a closed economy yielded an inverse relation between reinforcer availability and response rate, and Felton and Lyon (1966) found that an open economy yielded a direct relation. The present results are compatible with the latter studies. The selected range of VI schedules was used because the lowest value produced satia-

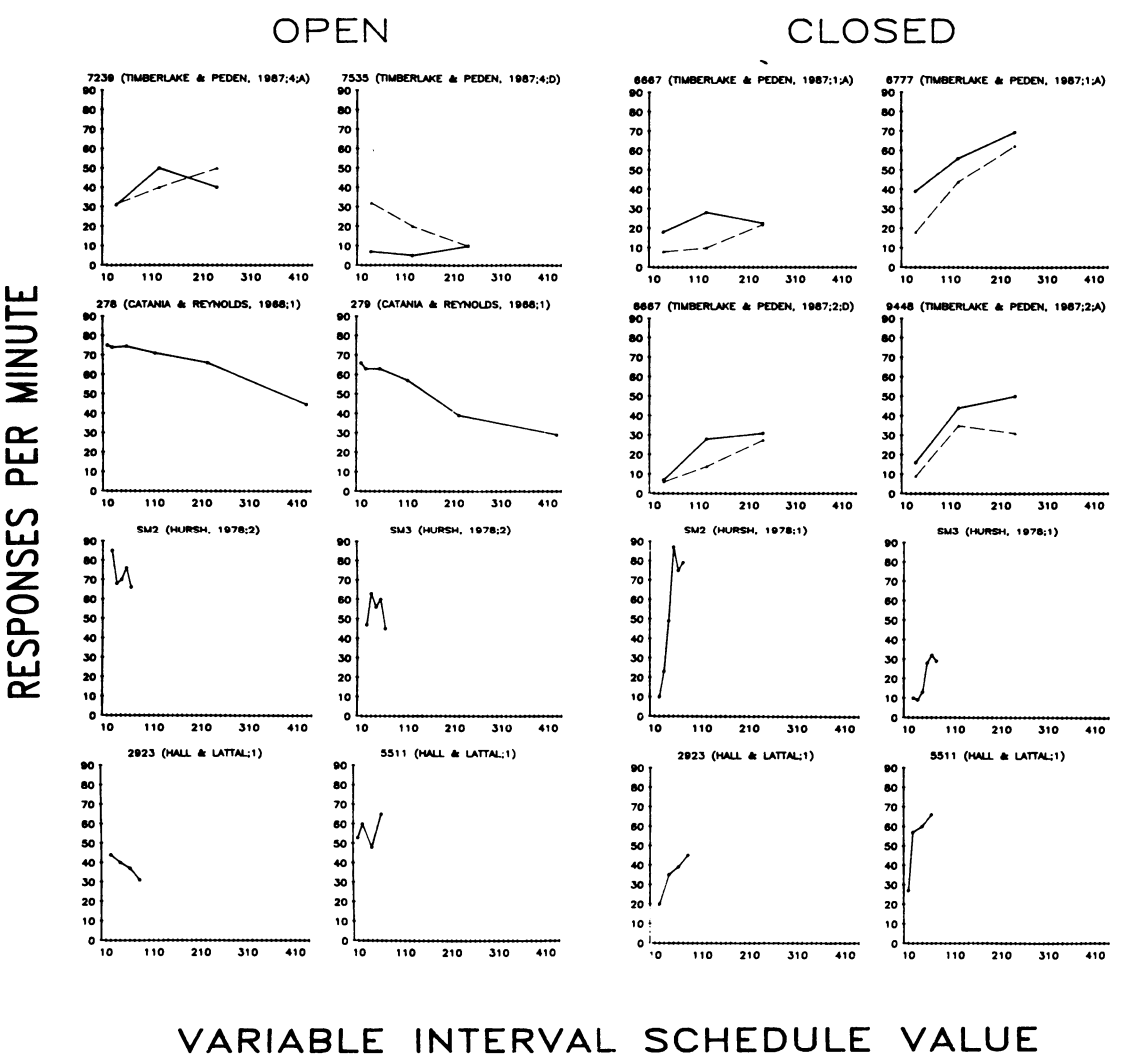

Fig. 3. Relations between response rates and reinforcement frequency (schedule value) in open (left) and closed (right) economies for the indicated experiments. In the Timberlake and Peden (1987) data, the solid lines indicate hopper durations of 0.05% and 0.5% of baseline eating times in open and closed economies, respectively, and the broken lines indicate 0.1% and 1% of baseline eating times. The single digits following the authors' names or dates indicate the experiment number; ascending and descending sequences of VI schedules are indicated by A and D, respectively.

tion in both subjects and the highest value led to an inability to maintain body weight. These and several intermediate values seemed to span a continuum of behavioral effects.

Figure 3 compares the present results to those of Timberlake and Peden (1987, Experiment 1—ascending series of schedules, Experiment 4), Hursh (1978, Experiments 1 and 2), and Catania and Reynolds (1968, Experiment 1). All data were converted to responses per minute, only VI data were presented, and only data representing selected hopper durations in Timberlake and Peden's study were used. The hopper durations used were 1% and 0.5% of baseline eating time in the closed economy and 0.1% and 0.05% in the open economy. The purpose of using these hopper durations was to approximate as closely as possible the durations of 3 s and 4 s used in the other studies. In addition, all data were plotted as a function of absolute VI schedule values rather than reward densities because it was not pos-

sible to calculate reward densities for studies in which baseline eating durations had not been measured.

The right panels of Figure 3 show inverse relations between response rate and reinforcer availability in each of the studies when closed economies were in effect. The data from Timberlake and Peden (1987) in Figure 3 are consistent with the other findings. The only exception, which is not plotted in Figure 3, is the function for Bird VI 6777 in Timberlake and Peden's Experiment 1, descending sequence of schedules, in which the hopper duration was 1% of baseline.

The left panels of Figure 3 show more variable functional relations between response rates and VI reinforcer frequency within and across studies when open economies were in effect. Timberlake and Peden (1987) obtained slightly inverse functions between response rate and reinforcer availability with Bird VI 7239, whereas direct and flat functions were obtained with Bird VI 7535. Data from Hursh (1978) are variable, but data from Subject SM2 suggest a direct relation between response rate and reinforcer availability. Catania and Reynolds (1968) obtained direct functions with all 6 subjects (Birds 278 and 279 are representative), although some variability in the data was observed when reinforcement occurred frequently. The present Experiment 1 obtained a direct function with Bird 2923, but the effect was more variable with Bird 5511. Direct functions with both birds were obtained in Experiment 2. All studies, therefore, showed evidence of a direct relation between response rate and reinforcer availability in open economies, although some demonstrated this effect more consistently than others. In any case, the effects of open and closed economies differed in each experiment in which comparisons of the two were made, either within or between subjects.

In reviewing Timberlake and Peden's (1987) data alone, it appears that the same (low) reward densities in closed and open economies yielded functional relations with similarities as well as differences. Data obtained from Experiments 2 and 4 (closed and open economies, respectively) were similar in that peak responding occurred at approximately the same points in each. Nevertheless, the functions obtained under the different types of economy were not identical. The closed economy yielded slightly bitonic functions (i.e., gradual inverse and direct relations) in 3 of 4 subjects. In addition, both inverse and direct relations appeared to fall on the same functions; that is, the variability of data points from the line describing the function was minimal. The open economy (Experiment 4) yielded more variable direct and inverse relations, and it was unclear whether these relations fell on the same functions. In order to demonstrate bitonicity, direct and inverse relations must fall on the same functions. It is possible that the greater variability in open-economy data represents a difference in the effects of open and closed economies. On the other hand, procedures used in Timberlake and Peden's open economy may have contributed to this variability. In contrast to the open-economy procedures of Catania and Reynolds (1968), Hursh (1978), and the present study, Timberlake and Peden allowed the proportion of total daily intake obtained through interaction with the reinforcement schedule to vary across conditions. It is possible that these differing proportions may produce different behavioral effects than would constant proportions.

As a secondary analysis, inspection of cumulative records in the present study (Experiment 1) revealed that with frequent reinforcement, response rates declined near the end of some closed-economy sessions. Moreover, the amount of decline varied across conditions providing differing frequencies of reinforcement. Differential within-session satiation was not a factor in the open economy because different conditions provided approximately the same number of reinforcers. To explore the contribution of within-session satiation to economic differences, open and closed economies were compared over a period of time, the first 30 reinforcers of each condition (see Table 2), in which satiation was less of a factor. With Bird 2923, differential within-session satiation did not mediate differences in the effects of open and closed economies. With this bird, partial-session data revealed the same inverse relations between open and closed economies as whole-session data. With Bird 5511, differential within-session satiation did not play a role in the open economy or in the VI 40-s and VI 60-s conditions of the closed economy, where reinforcement was less frequent. Satiation did occur, however, in the VI 10-s and VI 20-s conditions of the closed economy, those pro-

viding the most frequent reinforcement. For these conditions, partial-session data revealed higher response rates than whole-session data.

Within-session satiation also has been noted in prior studies of open and closed economies. Timberlake and Peden (1987) indicated that in their closed economy (Experiment 1), "Pecking rate was quite variable at higher reward densities because several birds frequently stopped eating about halfway through the session with the hopper still available" (p. 40). Because Timberlake and Peden presented data from entire sessions (total pecks), the shapes of their closed-economy functions may have been affected by differential within-session satiation. In Timberlake and Peden's open economy (Experiment 4), sessions ended after 20 food deliveries or 3 hr, whichever occurred first. Because the duration of food deliveries varied across conditions, differential satiation also may have occurred in their open economy. Hursh (1978) also noted differential satiation in his closed economy. According to Hursh, "Some food satiation and water acceleration was evident in the three conditions providing the most frequent food" (p. 482). Nevertheless, data presented from the first 15 min of the closed economy showed the same functional relations (but with slightly less slope) than data from the entire sessions. Differential satiation did not appear to be a factor in Hursh's open economy because, in all conditions, sessions ended after subjects obtained 150 food pellets. Thus, Hursh's data and some of the present data indicate that differences in the effects of open and closed economies maintain across a portion of the session in which within-session satiation is approximately constant across conditions. For this reason, it seems premature to conclude that behavioral differences in economic context are always due to this factor.

The present analysis underlines the need for further intrasubject comparisons of variables that affect reinforcement schedule performance in open and closed economies. The evidence reviewed here strongly suggests that different types of economies yield behavioral differences. However, the differences may not be as simple as inverse versus direct functional relations between response rate and reinforcement frequency, and some similarities may exist. Although bitonicity might occur in both open and closed economies, a more convincing demonstration of this phenomenon is needed.

REFERENCES

Catania, A. C., & Reynolds, G. S. (1968). A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* **11,** 327–383.

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

Felton, M., & Lyon, D. O. (1966). The post-reinforcement pause. *Journal of the Experimental Analysis of Behavior,* **9,** 131–134.

Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior,* **5,** 529–530.

Hursh, S. R. (1978). The economics of daily consumption controlling food- and water-reinforced responding. *Journal of the Experimental Analysis of Behavior,* **29,** 475–491.

Hursh, S. R. (1980). Economic concepts for the analysis of behavior. *Journal of the Experimental Analysis of Behavior,* **34,** 219–238.

Hursh, S. R. (1984). Behavioral economics. *Journal of the Experimental Analysis of Behavior,* **42,** 435–452.

Timberlake, W., & Peden, B. F. (1987). On the distinction between open and closed economies. *Journal of the Experimental Analysis of Behavior,* **48,** 35–60.

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