5-1989

An Examination of Open- and Closed-Economic Conditions in Operant Research

Craig R. Loftin
Utah State University

AN EXAMINATION OF OPEN- AND CLOSED-ECONOMIC CONDITIONS IN OPERANT RESEARCH

by

Craig R. Loftin

A dissertation submitted in partial fulfillment of the

requirements for the degree

of

DOCTOR OF PHILOSOPHY

In

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1989

DEDICATION

This endeavor is dedicated to the loving memory of Helen and Lawrence Loftin.

ACKNOWLEDGEMENTS

A dissertation, while an independent piece of work conducted by the student, is never completed in isolation or without the support of many individuals. A great deal of the success of the student is attributable to the setting events and contingencies that are arranged for him. Rather than being an exception to this rule, I believe that I may be its best example! Innumerable teachers, friends, colleagues, and, particularly, members of my family, have contributed to this undertaking. To all of you, I am grateful.

Dr. Carl Cheney provided support, direction and friendship throughout the endeavor. The other members of my committee, Dr. Phyllis Cole, Dr. Charles Salzberg, Dr. Sebastian Striefel, and Dr. Richard Young, supplied their expertise and wisdom, gained over many years of experience in conducting and applying both basic and applied research. Willing and able teachers and colleagues, all. Dr. Steven Hursh provided helpful guidance and suggestions at various stages of this work.

My wife, Linda, above all and everyone else shared in this and made it possible. Finally, Kara and Adam, our children, were ever patient, understanding, and helpful. Children who can, when asked what their father does, state proudly that, "He tests pigeons in the basement!", are truly exceptional.

Craig R. Loftin

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

ABSTRACT

An Examination of Open- and Closed-Economic

Conditions in Operant Research

by

Craig R. Loftin, Doctor of Philosophy

Utah State University, 1989

Major Professor: Dr. Carl D. Cheney
Department: Psychology

The effect of economic condition on the relation between responding and overall rate of reinforcement has been an area of recent interest in operant research. The present research was conducted to determine whether the manipulation of the economic condition, by the systematic manipulation of the provision of substitute food, has an effect on this relation and whether open- and closed-economies represent two opposing alternatives or two parametric extremes along a continuum. The results of two experiments conducted with pigeons using variable-interval and fixed-ratio schedules of reinforcement suggest that the manipulation of economic condition has a controlling effect on the relation between responding and overall rate of reinforcement, that open- and closed- economies are likely to represent points along a continuum rather than all-or-none conditions, and that the differences in the response-to- reinforcement relation between open- and closed-economies are likely due to an interaction of incentive and regulatory effects. Additionally, specific methodological considerations for further research in this area are suggested.

(130 pages)

CHAPTER I

INTRODUCTION

During its brief history, the field of behavior analysis has made considerable progress in producing many findings of scientific importance that are reliable and general and which have made significant contributions to the development of a science of behavior (see Honig & Staddon, 1977; Lattal & Harzem, 1984).

These advances have set the occasion for extending research in the field in additional directions, and recent research suggests that there are many opportunities to integrate other areas of knowledge into the science that are of interest to the behavior analyst. Such an integration may strengthen both the science of behavior and the area of knowledge that is integrated (Lattal & Harzem, 1984).

One such direction, which has received little attention and requires a great deal of additional research, is in the area of behavioral economics. Behavioral economics involves the integration of knowledge from the field of economics into the science of behavior (Hursh, 1984). Over a decade ago, Kagel and Winkler (1972) suggested that there were many ways that the fields of behavior analysis and economics could be enhanced through cooperative research. Hursh (1984) suggested that for such cooperative efforts to be productive, it is necessary to examine behavioral research methodology in terms of open- and closed-economies. Traditionally, the general methodology of the experimental behavior analyst has involved food-depriving an animal to some predetermined and arbitrary weight below the animal's free-feeding weight. The animal is then placed in an apparatus that restricts its environment. Thus, the stimuli presented to the animal and its opportunities to respond are under the control of the experimenter. Through the experimenter's manipulations, the animal is provided the opportunity to feed by responding to presented conditions. The length of the session and the amount of food consumed by the subject, both during the experimental session and at other times, are controlled by the experimenter. Frequently, the length of the session prohibits the animal from consuming an amount of food that is necessary for it to maintain the predetermined state of deprivation and must therefore be provided with intersession substitute food. Throughout the experiment, the animal is never restored to its free-feeding weight (Collier, Hirsch & Kanarek, 1977).

In behavioral economic terms, this general methodological approach represents subjects working in an open-economy (Hursh, 1980). In such an arrangement, the subject is held at a fixed body weight and given supplemental, or substitute, feedings to keep food intake constant, independent of the subject's interaction with the schedules in effect during experimental sessions. Such an arrangement is distinguished from a closed-economy (Hursh, 1980), in which the subject's total daily consumption of food is entirely dependent on its own responding in interaction with the schedules in effect during the experimental sessions. In a closed-economy experiment, no substitute food is provided the subject, and the animal is neither food-deprived nor is its weight artificially maintained prior to or during the experiment.

The importance of this distinction lies not in the methodological difference between the two economic conditions but rather in the differences in responding that have been obtained in experiments employing the distinct conditions. It has been reported that in open-economies overall response rate decreases as overall rate of reinforcement decreases, while in closed-economies overall response rate increases as overall rate of reinforcement decreases (Hursh, 1978, 1980, 1984).

In the experimental analysis of behavior there has been a nearly exclusive reliance on the open-economy method in an effort to establish an unbiased experimental setting; that is, one which neutralizes species-specific and extraneous environmental influences over behavior. Consequently, the attention of the behavior analyst has been directed in clear and specific directions, which has produced many principles that are scientifically important, reliable, and general. Nonetheless, as much as responding in open-economies is said to differ from that in closed-economies, it is necessary to take into consideration the role played by this heretofore little-investigated aspect of environmental control of behavior.

It is unlikely that a more complete understanding of responding within the context of a closed-economy would invalidate the principles derived from open-economy research. Principles such as reinforcement, shaping, and punishment, among others, are likely to operate in much the same way in either economic context. However, improved understanding will broaden the general experimental methodology in behavioral research and likely strengthen the science. Inasmuch as research findings prove to be empirically valid and unique when compared to established behavioral principles and concepts, they will contribute to the formulation of a general theory of behavior (Sidman, 1960). Such could be the case with investigations into closed-economy behavior.

Statement of the Problem

While the distinction between the use of open- and closed-economy research is being made with increasing frequency, there still remain critical questions, the answers to which will allow a more thorough understanding of the control that this manipulation (open- vs. closed- economy) has on behavior. To date, all but one (S.R. Hursh, personal communication, December 12, 1987) of the studies that have investigated responding under these two conditions have treated them as two alternatives, rather than as opposing extremes on a continuum. As such, no one has identified the critical component of the economic condition that accounts for the reported difference in responding: from a direct relationship between overall response rate and overall rate of reinforcement in an open-economy to an inverse relationship between these factors in a closed-economy (Catania & Reynolds, 1968; Hursh, 1980, 1984).

The purpose of this research was to determine whether a shift from an indirect relation between overall response rate and overall rate of reinforcement in an open-economy to a direct relation between these factors in a closed-economy could be obtained by manipulating the amount of substitute food provided to the subject. Further, by manipulating the amount of substitute food, it would be possible to determine whether open- and closed-economies represent two opposing alternatives or two extremes of a continuum.

Specifically, the research was conducted to answer the following questions:

1. In a closed-economy, in which total daily food consumption is dependent on responding on presented variable interval schedules of reinforcement, what is the relation between overall response rate and overall rate of reinforcement?

2. In an open-economy, in which response-independent, between-session substitute food is provided to the subject by the experimenter, what is the relation between overall response rate and overall rate of reinforcement on variable interval schedules of reinforcement?

3. Given that there is an inverse relation in a closed-economy and a direct relation in an open-economy between overall response rate and overall rate of reinforcement, do these two economic conditions represent opposing alternatives, or are they two extremes along a continuum?

CHAPTER II

REVIEW OF THE LITERATURE

The distinction between an open- and a closed-economy is an important one. Studies conducted over the years have produced data that, when compared, illustrate critical differences in responding between subjects exposed to the same or similar contingencies of reinforcement but within the context of these differing economic conditions (Collier, Hirsch, & Hamlin, 1972; Felton & Lyon, 1966; Findley, 1959; Hursh, 1978, 1980, 1984, S. R. Hursh, personal communication, December 12, 1987; Lea & Roper, 1977; Logan, 1964; Lucas, 1981). Furthermore, the distinction is playing an increasingly important role in the integration of the fields of microeconomics and the experimental analysis of behavior (S. R. Hursh, personal communication, December 12, 1987). In this review of the literature, the area of behavioral economics will be introduced, and the distinction between open- and closed-economic conditions, as well as the evidence in support of this distinction will be examined. Finally, alternative views regarding the distinction will be presented.

Behavioral Economics

Although Skinner noted the parallel between ratio schedules of reinforcement in the operant laboratory and the economic principles of price-rate wages and commission selling as early as 1953 (Skinner, 1953), it has only been over the last decade that the traditional insularity between the fields of economics and behavior analysis has begun to fade. Economists have begun to enter the laboratory to conduct experiments with limited numbers of subjects, both human and nonhuman, in controlled environments. Likewise, behavior analysts have begun to incorporate economic principles into their experimental design and into the analysis of experimental results (Green & Kagel, 1987). Interest and activity in the area has recently become so active that the Society for the Advancement of Behavioral Economics (SABE) has been formed. The fourth annual conference of this society was held in June, 1988, at San Diego State University (Roger Frantz, personal communication, June 18, 1988).

The value of the integration of research findings of the fields of behavior analysis and economics is presented most recently, and perhaps most clearly, by Hursh (1984). In this conceptual article, Hursh discusses the validity and utility of economic concepts, such as demand elasticity, commodity substitutability, and complementarity, among others, in the interpretation of the results of behavior analytic experiments. It is worthwhile to briefly introduce these concepts here in order to illustrate the need to more closely examine the open-/closed-economy issue from the behavioral economic perspective.

According to economic theory, the demand for a commodity is affected by its price (Hoag & Hoag, 1986). If the consumption of a commodity is reduced due to small increases in the price of that commodity, the demand for the commodity is said to be elastic. Conversely, if increases in the price of the commodity have little effect on the consumption of the commodity the demand for that commodity is said to be inelastic (Hoag & Hoag, 1986). A typical example of a commodity the consumption of which is inelastic is food. Despite even large increases in the price of essential food items, consumption levels generally remain the same. On the other hand, luxury items (items nonessential to survival) are typically affected by small increases in price. That is, as the price increases, consumption of these commodities decreases. Thus, the demand for these luxury commodities is considered elastic.

Commodity consumption is also affected by the substitutability and/or the complementarity of alternative commodities (Hoag & Hoag, 1986). Commodities are said to be substitutable when they are functionally equivalent, such as in the case of food available from two sources. Foods available from Source 1 can be substituted with foods available from Source 2. Commodities are said to be complementary when the consumption of one affects the consumption of the other. Record players and records are complementary commodities. When consumption of record players increases, consumption of records also increases. In the case of research conducted with pigeons, food and water would be considered complementary commodities: as food consumption increases, so does the consumption of water (Zeigler, 1976). These economic concepts, substitutability/complementarity and elastic/inelastic, may interact. Thus, in the case of complementary-elastic commodities, as the price for one increases and demand for it decreases, demand for the other commodity would also decrease. Increases in the price of record players will decrease demand for both record players and records. In the case of substitutable-inelastic commodities, as the price of a commodity from Source 1 increases consumption of the commodity from

Source 2, where there has been no price increase, would increase. Of course, this is a simplification of the economic model. There are many economic principles that are involved in commodity consumption. However, this level of analysis suffices for the present need to establish the value of these economic principles to the behavior analyst.

Hursh (1978) demonstrated the utility of integrating these economic concepts in the analysis of behavior. In a simple choice experiment with monkeys in a closed-economy, food and water were made available for responding on a three-lever concurrent schedule. Two schedules were held constant at variable interval (VI) 60 s, one providing single pellets of food and the other providing single squirts of water. The third lever provided identical pellets of food as those delivered for responses on lever 1, but for responding on VI schedules, the mean values of which varied from 30 s to 480 s. The results of the experiment were said to illustrate the substitutability and complementarity of commodities. As the VI value on the third lever increased, responding on that lever decreased and responding on the first lever increased. That is, as the price of food (inter-reinforcement-interval [IRI]) from Source 2 increased, responding for food from Source 1 increased. In fact, nearly perfect matching (Herrnstein, 1961) was obtained.

This is a basic demonstration of the consistency of the economic concept of substitutability of inelastic commodities with the behavioral principle of matching. While this consistency permits an integration of the products of the two sciences, neither is necessary to the other.

That is, either concept independently predicts these experimental results.

In the case of responding for water in this same experiment, Hursh (1978) found that as responding under the constant food schedule (VI60 s) increased, responding on the constant water schedule (VI60 s) decreased. That is, at the lower VI schedule values on the variable VI food-reinforced lever, reinforcement was more frequent than at the VI60 s schedule in effect on the constant VI60 s food-reinforced lever. At higher reinforcement rates, more food was obtained, and thus more water was required. Conversely, when the rate of reinforcement dropped as the subjects increasingly responded under the constant VI60 s condition, less food was obtained, and responding for water decreased. These results are predicted by the economic concept of commodity complementarity. However, the behavioral concept of matching would have predicted matching, because reinforcers were equally available for responses on either response key. Food and water were both available on VI60 s schedules and the matching relation would, therefore, predict responses to be distributed equally on the two keys. Matching was not obtained, however. Rather, counter matching (Rachlin, Green, Kagel, & Battalio, 1976) was. It is suggested that this discrepancy is due to the fact that matching theory does not account for the nature of the reinforcers utilized. Integrating the economic concept of complementarity into this behavior analysis assists in clarifying why counter matching was obtained in this instance. This demonstrates the value to the experimental analysis of behavior of the integration of economic concepts.

This and other laboratory experiments with non-human subjects have been conducted in an attempt to create situations that are analogous to human ones and that permit an examination of economic principles. It is possible to examine income and commodity price interactions, for example, by using behavioral methodologies. By establishing a procedure in which animals have only a fixed number of responses available per session (income), the effects of changes in price (schedules) of reinforcers can be studied as a function of the demand for the reinforcer (deprivation).

One such experiment was conducted by Elsmore, Fletcher, Conrad, and Sodetz (1980). Baboons were given a choice between food and heroin infusion. Under experimental conditions that were typical in that there was no constraint on the number of responses that could occur in a session, neither food nor heroin choices were very dramatically affected by price, responding on an FR requirement. Then the procedure was changed. The baboons were given a fixed income of responses per day that could be allocated either for the purchase of heroin or for the purchase of food. At this point the differential demand for the two reinforcers was noticeable. When both commodities were inexpensive (low FR requirements for both), the baboons chose each of them roughly equally, distributing responses nearly equally between the two response keys. As the cost increased (FR requirements were increased for both), demand for heroin dropped while demand for food stayed constant. Food demand was inelastic while heroin demand was elastic, a difference that could only be revealed when the animals' income was controlled by the experimenter.

These and other economic concepts have been utilized in operant research with humans (Battalio, Kagel, Winkler, & Winett, 1979; Fischer, Winkler, Krasner, Kagel, Battalio, & Bassmann, 1978a; Fischer, Winkler, Krasner, Kagel, Battalio, & Bassmann, 1978b; Schroeder & Barrera, 1976; Winkler, 1970, 1971, 1973). These studies were conducted using token economies.

As examples, Winkler (1971, 1973) conducted studies at a state institution for psychiatric clients in Australia. Similarities were demonstrated between token economies and national economies in terms of income acquisition and its expenditure, the use of credit and savings, stock of savings, and the percentage of income spent on luxuries as compared to essential goods in terms of demand elasticity. A token economy experiment conducted in a sheltered workshop by Schroeder and Barrera (1976) produced results similar to those obtained by Winkler regarding demand elasticity.

Winkler (1980) suggested that the results of these studies indicate that economic principles can predict behavior in token economies and that behavior in token economies may be useful in generating economic principles because token economies are simple, small closed-economic systems. Thus, from her analysis, Winkler suggested that token economies can serve as laboratories for the study of large economic systems.

As described in the next section, based on the reported discrepancies between responding in open- vs. closed-economies, it would appear that the distinctions and similarities between token and national economic systems would have to be carefully considered. It would appear that a direct comparison between a closed-system token economy and a large-scale (e.g. national level) system may be inappropriate. In large-scale economies there are often alternative sources of commodities that are not available in closed-system token economies. Furthermore, many token economies are used with children in noninstitutional settings (Alvord, 1978; Kazdin, 1977). In such cases, the economic system may not be totally closed, as children may have access to substitutable reinforcers outside of the experimental setting, much in the way animal subjects frequently have access to between-session substitute food in open-economy experiments.

In summary, the integration of the science of behavior and the science of economics holds promise of making contributions to both. Cross fertilization is already being achieved through the exchange of methodologies and the examination of experimental findings in light of the principles and tenets of each science. The work on this integration is recent and a great deal of work remains. The possibilities of integration may be facilitated or delimited by research in the area of open- vs. closed-economies.

Open- and Closed-Economies

Increasingly, the distinction is made in the operant literature between open- and closed-economies (see Brady, 1982; Collier, 1983; Delius, 1983; Hursh, 1978, 1980, 1984; S. R. Hursh, personal communication, May 17, 1987; Lucas, 1981; Mellitz, Hineline, Whitehouse, & Laurence, 1983; Norborg, Osborne, & Fantino, 1983; Rachlin, 1982). In this section, information pertinent to the investigation into the distinction will be presented, as will be the related research that has been conducted to date.

Performance Under Interval Schedules of Reinforcement

To fully appreciate the reported distinction between responding in an open- vs. a closed-economy, it is necessary to discuss responding maintained by interval schedules of reinforcement.

Conventional wisdom regarding behavior maintained by variable-interval (VI) and fixed-interval (FI) schedules of reinforcement has a long history and a considerable research base. It is held that the relation of overall rate of responding to overall rate of reinforcement under these simple schedules is a monotonically increasing and negatively accelerated function (Catania & Reynolds, 1968). That is, as interreinforcement intervals increase, rate of responding decreases. Support for this is considerable, both when the simple schedule is utilized as well as when the simple schedule is employed in concert with other schedules of reinforcement, across species, and with subjects maintained at varying states of deprivation. Skinner (1936), Sherman (1959), and Wilson (1954) each reported such a function with rats on FI schedules. Schoenfeld and Cumming (1960) and Farmer (1963) reported similar functions with rats using VI schedules of reinforcement. In 1958, Clark obtained this function when testing his rat subjects at varied levels of deprivation. The results of an experiment reported by Kaplan (1952), which employed FI schedules of escape, suggest that this function may also obtain for schedules of negative reinforcement.

So extensive is the research foundation for this function that common descriptions of behavior maintained by interval schedules often present the function as lawful. In one widely utilized undergraduate textbook, Elementary Principles of Behavior by Whaley and Malott (1971), a pigeon's responding under a VI schedule is described. They state that:

> It is true that the smaller the average interval between opportunities for reinforcement, the higher the rate of responding will be. Thus, if two or three days' wait was required between opportunities, we would expect an extremely low rate of response, perhaps as low as one peck every two or three hours. (p. 131)

In addition, it has been reported in VI research that as intervals increase, the responding of some subjects approach invariance. That is, above a certain interval value, which differs from subject to subject, responding is no longer sensitive to parameter changes; a uniformly low rate of responding is maintained despite increases in the interval value. Herrnstein (1961) and Sidman (1960) have referred to such responding as a "locked-rate." Sidman, in his discussion of variability in performance, discusses "locked-rates" in VI responding:

> The important factor is that the presentation of grain is consistently preceded by a given rate of responding. The rate itself becomes conditioned, however adventitiously. Once this happens, of course, behavior maintained by a variable-interval reinforcement schedule is no longer a satisfactory baseline from which to measure the effects of other variables. The response rate, itself conditioned, loses a great deal of its sensitivity. Furthermore, discrepant data are likely to cause useless controversy if such a "locked-rate" is not recognized. (p.177)

Catania and Reynolds (1968), on the basis of a series of six experiments in which an open-economy methodology was employed, concluded that the rate of responding maintained by an interval schedule is not dependent on the overall rate of reinforcement provided, but rather on the summation of different local effects of reinforcement at different times within the intervals.

Finally, as early as 1958 conventional wisdom regarding the sensitivity to VI schedules of reinforcement had led to their use for calibration purposes, such as in pharmacological research (Clark, 1958).

Reports of Discrepant Responding Under VI Schedules

It is important to note that the monotonically increasing, negatively accelerated response function under VI schedules has been generated using open-economy methodology.

The initial empirical comparison of open- and closed-economic systems was reported by Hursh (1978), as was mentioned earlier. As a result of this one study, Hursh presented data that raise questions about the responding maintained by VI schedules of reinforcement. In this closed-economy study, in which monkeys obtained their complete food ration during experimental sessions, Hursh obtained a monotonically increasing, positively accelerated function as the interval was increased from 20 s to above 50 s. Only at interval values above 50 s did responding begin to deteriorate. Unlike the open-economy experiments cited in the previous section, in which response rate was directly related to rate of reinforcement, Hursh's results demonstrated that in a closed economy, response rate is inversely related to rate of reinforcement.

In 1980 Hursh introduced the terminology "open- and closed-economies," and further detailed these conditions in 1984 (Hursh, 1980, 1984, 1986). At a symposia on the topic held at Harvard in 1986, Hursh defined open- and closed-economies and the consequences of the distinction:

> Stated most simply: in a closed-economy the consumption of the reinforcer, including time in the test system and in the home cage, depends entirely on the amount of responding by the subject during the test. The experimenter exerts no control over the total level of consumption, neither by way of a minimum level or an upper limit, except to define the relationship between responding and reinforcer deliver, the schedule of reinforcement, or <u>supply schedule</u> to use economic terminology. There is no compensation made for reduced levels of consumption.
>
> The open-economy, which is typical of most animal testing situations reported in the behavior analysis literature, is an environment in which the consumption of the reinforcer, considering both time in the test and time in the home cage, is held constant by the experimenter or is varied by the experimenter independently of the subject's responding. The experimenter serves as a compensation mechanism for any variations in consumption that occur during the test, such that, on a daily basis, overall consumption is not influenced by variations in the subject's performance. This situation is deliberately designed to minimize the influence of biological feedback, that is, to minimize what are presumed to be "satiation effects" and "deprivation effects"; the potential for satiation and deprivation changes are said to complicate the analysis of the pure "strengthening effects" of reinforcement. The unintended consequence of this approach has been a lack of generalizability to conditions which simulate the natural environment and permit the subject to control daily consumption and exhibit regulatory or economic processes. This limitation is further compounded by evidence that the differences between open- and closed-economies, indeed, cannot be readily explained in terms of daily changes in deprivation. (pp. 1-2)

became the preferred key In a personal communication (Hursh, personal communication, May 4, 1987), Hursh reiterated the necessary relation between daily consumption and response rate:

> I have attempted to make the definition clear in my several papers, but still find some people missing the point. The main error is not recognizing the necessity for daily consumption and response rate to co-vary. Some researchers have suggested that I "control" for deprivation effects in a closed-economy by holding daily consumption constant, eg. ending sessions after a fixed number of large reinforcers and providing no supplemental food. This is not a closed-economy since daily level of consumption does not depend on level of responding. To be as blunt as possible, the so-called confound between response rate and daily consumption in a closed-economy is, in fact, the defining feature of the system. This is the same "confound" that exists in most natural foraging settings and to the extent that it determines the outcome of the experiment, is crucial to a laboratory simulation of natural foraging. The importance of this dependency in determining the closed-economy results is an empirical question. (p. 1)

In perhaps the most extensive investigation of pigeon responding in a closed-economy, Lucas (1981) produced results similar to those obtained by Hursh (1978). Lucas maintained his subjects in experimental chambers over a period of approximately nine months, over the course of three experiments, during which time no substitute food was provided to them.

In his final experiment, Lucas varied the length of FI schedule values and established that there was an inverse relationship between overall response rate and overall rate of reinforcement. As the number of reinforcements decreased from 4 per minute to 1 per minute, the rate of responding increased from approximately 5 responses to approximately 100 responses per minute for each of his three subjects. Individual differences in absolute response rate were apparent from pigeon to pigeon, but the function was similar in the case of all subjects.

The results of experiments conducted by Hursh (1978, 1980, 1984) suggest that the subjects are sensitive to between-session, or delayed conditions. There is additional support for this notion. In economic terms, the between-session provision of food in open-economy research serves as an alternative source of food, a substitutable commodity. Mellitz et al. (1983) conducted an experiment in which responding had two functions: prevention of aversive stimulation and reduction of the length of the avoidance session. The results of the experiment also indicated that the subjects were sensitive to events on a time scale other than that of immediate consequences. That is, it was demonstrated that behavior may be sensitive to its long-term consequences under conditions in which more immediate consequences might be expected to prevail.

In the experiment, equal shock-avoidance contingencies were established on two response keys. As responding on the two keys stabilized, an additional contingency was added to one key. This contingency reduced the total session time by one minute for each response made on the key. This then became the preferred key across subjects. Once responding stabilized, the session-shortening contingency was programmed for the opposite key and dropped from the original key on which it had been programmed. Response preference shifted to the opposite key. From these results, Mellitz et al. (1983) suggest that responding during an experimental session is sensitive to between-session conditions.

Although this study was not conducted to explore the distinction between open- and closed-economies, Mellitz et al. (1983) interpret their results in terms of open- vs. closed-economies, in which the effects of variables operative within conditioning sessions interact with the availability/nonavailability of food outside the sessions. The researchers conclude that it is possible both avoidance and appetitive responding may more fully be accounted for by extending the range of conventional variables, such as the frequency and temporal distribution of consequential events.

In 1983, Norborg, et al., investigated the effects of component duration on the relative and absolute rates of responding on multiple FR schedules. Specifically, they examined the effects of both component and session duration on these schedules. Transitions between components were response independent. That is, changes from FR component to FR component were based on time rather than on number of responses made. On the basis of Hursh's (1980) argument that responding in open- and closed-economies differs, these researchers judged the need to examine the effects of session duration. They were concerned that when food was freely provided after a relatively short experimental session, the relation between the subject's performance in the experiment and its level of consumption might be less constrained than when all their food was earned in the chamber. Therefore it is likely that in multiple schedules, performance is likely to be effected by session duration. Unfortunately, the results from this study do not further our understanding of responding in open- and closed-economies, because they controlled only for session duration and not response independent intersession consumption of food that is a defining characteristic of a closed-economy (Hursh, 1980).

In 1986, Hursh conducted the first systematic comparison of open- and closed-economic systems in two experiments. In the first, the amount of between-session food made available to four monkeys was gradually increased. Sessions were twelve hours long, and intra-session reinforcement was available for responding according to FR schedules. The FR schedule was increased each day in 21 steps of 20% from FR 10 to FR 372. At the end of each session, free food equal to one free pellet of food, or one-third or two-thirds the amount normally earned during the FR 10 baseline sessions was immediately provided, according to the condition. The results of the experiment were consistent for three of the four subjects. Although Hursh indicated that the pattern of responding of the fourth monkey varied in an "interesting way," he did not offer an explanation. The data from the three monkeys indicated the demand for food was relatively inelastic when the subjects responded for all but one of their daily food pellets. However, as increasing amounts of inter-session food were made available, within-session demand for food decreased systematically with the price of that food. That is, as the FR requirement increased and extra-session food was available, fewer food pellets were consumed during the session. Within-session consumption also declined as extra-session food availability was increased. These results show that free food delivered after the work session can have strong effects on the sensitivity of consumption to price increases, as well as sensitivity to between-session conditions.

In the second of these two unpublished experiments, the effect of varying the immediacy of the availability of external food was investigated (Hursh, 1986). On the basis of economic theory that suggests future returns on investment are discounted when compared to current returns, Hursh judged that by reducing the delay, the discount would also be reduced, and the relative value of the free food would increase compared to the food purchased under the FR schedule. Thus, the substitution value of the extra-session food and the elasticity of the demand for food during the session were both expected to increase.

Using three of the monkey subjects from Experiment I, work sessions were changed from a single 12-hour long period to four one-hour sessions. In the baseline condition, total daily consumption was limited to that obtained during the sessions. In the second condition, 20 min access to food was available on a continuous reinforcement (CRF) schedule, immediately after the end of the fourth work session. In the third condition, four 5 min CRF periods followed immediately after each of the four work periods, thus reducing the maximum delay to free food to one hour during any work session. In all three conditions, the FR requirement was increased in twelve 40% increments, from FR 10 to FR 420.

Hursh (1984) found that the subjects consistently compensated for food losses during the sessions by consuming additional food during the CRF periods, such that no systematic changes occurred in total daily consumption of food across increases in FR requirement or across conditions of increased immediacy of food. It was also found that the sooner the extra-session food was delivered after the termination of the work session, the within-session demand for food decreased as predicted.

Hursh (1984) concludes that the high elasticity of demand for food in the conditions that represented the most open economies in the two experiments resemble demand for a luxury good (one that has many substitutes), rather than a good that is a biological necessity for survival. On the other hand, the lack of elasticity of demand on those most closed economic conditions reflects the demand for a biologically required commodity for which there are no available substitutes. Hursh states the importance of this distinction to be that

> ...studies of operant behavior in open-economies which prevent biological feedback are most useful for illucidating the principles of behavior reinforced by non-essential commodities; by contrast, studies in a closed-economy are useful for illucidating the principles of behavior reinforced by a variety of commodities, both non-essential and essential. (p. 13)

A recent systematic investigation comparing the performance in open- and closed-economies was conducted by Imam and Lattal (1988). Little information is currently available about this research, other than that it assessed the effects of combinations of VI60 s and variable-time (VT) 60 s schedules of reinforcement in 1 hr open- and 4 hr closed-economy sessions, using within-subject comparisons of three pigeons' key pecking. Response rates were found to be generally higher in the open-economy than in the closed-economy conditions, with both the VI and the VT alternative food. The effect, however, was not consistently strong. Also, response distributions during sessions varied between the open- and closed-economy conditions. In the closed-economy, each pigeon showed bouts of responding and pausing with the VI alternative that was absent with the VT alternative. Imam and Lattal conclude that their results further support the distinction between open- and closed-economies.

A Challenge to the Distinction Between Open- and Closed-Economies

Timberlake (1984) challenges the assertion that there exists a distinction between responding in open- and closed-economies. In a study conducted in 1984, Timberlake sought to examine the time period during which subjects integrate input in making choices about distributing their resources. Timberlake's subjects, two rats, had two opportunities to feed each day. The first was made available according to the subject's responding on a progressive-ratio schedule of reinforcement. The second was a free-feeding opportunity that was provided to the subject after some predetermined delay following the termination of the progressive-ratio schedule component of the daily session. The progressive-ratio component lasted for one hour, or until the subject had consumed its' within-session allotment of food. This allotment was a percentage based on free-feeding baseline data. The delays between the termination of the progressive-ratio schedule component and the onset of the free-feeding component of the daily session was varied, in non-sequential fashion, by either 1, 2, 4, 7, 10, 16, 20 or 23 hours for both subjects.

The results of Timberlake's (1984) study demonstrated that the animals worked for a considerable number of food pellets during the progressive-ratio component of the session, despite the fact that pellets were freely available during the free-feeding component of the sessions. Responding within the progressive-ratio component of the sessions was consistent with a direct relation between overall rate of reinforcement and overall rate of responding, regardless of the ratio size. It was also demonstrated that there was little effect of the delay time between the work and free sessions.

Timberlake (1984) points out that because his procedures employed an open-economy, in that substitute (response independent) food was provided, an inverse relation should have been obtained between overall rate of reinforcement and overall rate of responding, based on the open- vs. closed-economy literature (Hursh, 1980, 1984). Instead, as the severity of the schedules increased (as the price of the commodity increased), and the overall rate of reinforcement decreased, there was a corresponding increase in the rate of responding, as reported in the literature on responding in closed-economies. Timberlake concluded that the distinction between open- and closed-economies can be questioned, and that behavioral differences reported for open- and closed-economies are based on differences in the severity of the schedule, rather than on the type of feeding regime employed. He maintained that this was so because the effects of an open-economy were presumed to be based on the anticipation of later food. His results showed no effect of future feeding on responding within the progressive-ratio component of the sessions, even when free-food was provided within an hour after the end of the work component of the session.

There are several issues that must be pointed out about the Timberlake (1984) study. First, a ratio schedule of reinforcement was utilized to maintain responding in the study. This is unlike those studies cited that resulted in a direct relation between overall rate of reinforcement and overall response rate in an open-economy, in which interval schedules of reinforcement were employed. In the case of ratio schedules, overall rate of responding is inversely related to overall rate of reinforcement by definition. Each response is essential to the eventual delivery of a reinforcer. As the ratio required for reinforcement increases, the rate of reinforcement decreases. On the other hand, in the case of interval schedules, only one response is required for reinforcement, regardless of the length of the interval involved. Thus, only in the case of interval schedules is the relation between rate of responding and rate of reinforcement free to co-vary from direct to inverse, or from inverse to direct.

That Timberlake's (1984) subjects did not show sensitivity to the availability of free-food, even within one hour after termination of the progressive-ratio component of the sessions, is also arguable. Timberlake states:

> There was no measurable effect of free future food on current responding. Instead, the rats appeared to treat the work session as an entirely self-contained world, increasing their bar pressing with the severity of the progressive-ratio schedule in partial compensation for reduced access to food.... (p. 121)

Timberlake (1984) points out that the provision of a specific average number of pellets was needed to maintain baseline weights of his subjects. The number of pellets available during any 24-hour period was based on this average. By examining the data available, it is apparent that throughout the experiment, both subjects typically consumed approximately only one-third of this daily intake requirement during the progressive-ratio component of sessions. In fact, the number of pellets consumed during these work sessions was fairly constant within subjects, and varied little across progressive-ratio or delay conditions. Only when the free-food component of sessions was delayed by more than 20 hours was there a remarkable degeneration of responding during the progressive-ratio components of the sessions. The remaining two-thirds of the subjects' daily intake was consumed during the free-food component. Perhaps Timberlake's subjects did not show sensitivity to differing delays between termination of the progressive-ratio and the onset of the free-feeding components of sessions, but they clearly did show sensitivity to extra-session free food.

Finally, Hursh (S.R. Hursh, personal communication, May 17, 1987) indicated that Timberlake's (1984) results may have been due to the restricted range of schedule values that he employed in his study.

Thus, it is likely that Timberlake's (1984) findings and conclusions were due to procedural differences between his study and others examining the open- vs. closed-economy responding phenomena, and the interpretation of the resulting data.

Despite the limitations of Timberlake's results (1984), the notion that delayed contingencies (i.e., the delivery of inter-session free food) are not integrated into within-session responding is not without precedence. It has been demonstrated that when given the choice between two concurrently available rewards that differ only in size (i.e., more vs. less access time at each reinforcer delivery, or larger vs. smaller rewards), organisms will consistently choose the larger alternative (Rachlin & Green, 1972). However, when the choice that is presented offers an immediate, but small reward, or a delayed, but larger reward, the smaller, immediate reward is consistently chosen. This was demonstrated by Fantino (1977) using concurrent chain schedules. These findings are presumably the result of the temporal delay in the delivery of the reinforcer.

Research has variously suggested that the limits of the temporal delay between response and reinforcer delivery is limited to seconds (Grice, 1948), 5 to 6 minutes (McSweeney, 1982), 15 minutes (Hodos & Trumbule, 1967), hours (Boulos & Terman, 1980) and seasons (Kayser, 1965). While this research base involves widely differing methodologies and subject species, it is clear that there is no definitive research on this topic. What is clear, however, is that in order for the distinction between open- and closed-economies to hold, it is necessary that an organism's current responding must take future rewards into account.

In summary, it appears that economic and behavioral principles may facilitate understanding in each of these fields. Yet, it is apparent that the issue of open- vs. closed-economies must be clarified. As clarifications are made, it is unlikely that they will invalidate the findings of the open-economy research. They do, however, suggest that the earlier findings are restricted, and indicate the need for additional investigation into the differences between open- and closed-economy responding in operant research. It is the purpose of this research to investigate these considerations.

CHAPTER III

GENERAL METHOD

Subjects

Four experimentally naive, adult male Waldina pigeons served. The pigeons lived in home cages, where they had free access to Purina Pigeon Chow and water 24 hrs per day, during a two-month period prior to the beginning of the study. Each pigeon's ad lib weight was established and its mean weight determined over the last five days of this period. Once the study began, food was removed from the home cages and was available only during 11.5 hr daily sessions in the operant chamber. Water continued to be available in the home cages, however. Throughout the study, the birds were not food-deprived, except during the 12.5 hrs that they were in their home cages each day.

Schedules of Reinforcement

Variable interval (VI) schedules of reinforcement were employed throughout, and were programmed exclusively on the right response key in each experimental chamber. The Fleshler/Hoffman formula (Fleshler & Hoffman, 1962) was used to generate the variable intervals. This formula produces intervals that are not predictable by the subject because reinforcement occurs with a given probability that remains constant as a function of time since reinforcement. It is, therefore, widely used in operant research (E. K. Crossman, personal communication, April 1, 1987). In open-economy phases of the experiments, a fixed-ratio 1 (FR1) schedule of reinforcement for the delivery of substitute food was employed. This schedule, when active, was present for pecks on the left response key in each experimental chamber.

Apparatus and Data Recording

Two Lehigh Valley Electronics (LVE) Model 1519 test cubicles, containing LVE Model 1438, 3-key intelligence panels were used. Only the left and right response keys of each test cubicle were used throughout the study. The center response key remained dark at all times. A minimum force of approximately 0.15 N was required to operate the response keys.

During Experiment I, a single LVE pigeon grain hopper delivered reinforcers, which consisted of 4 s access to the raised, chow-filled hopper. Purina Pigeon Chow was utilized exclusively during Experiment I. In order to minimize error in the usable duration of the hopper-lift, a constant 0.4 s were added to the 4 s access. The 0.4 s allowance had been previously reported as the minimum head transit time from the response key to the food hopper (Lucas, 1981). Thus, the actual duration of the hopper lift was 4.4 s. Markings on the grain hopper allowed the amount of feed consumed per session to be closely estimated. During Experiment II, Davis Scientific Instruments Pellet Dispensers, Model PD-104, delivered Bio-Serv dustless, 45 mg precision pigeon pellets when reinforcement was signaled. Each reinforcement consisted of the delivery of one pellet that was dropped into the hoppers that had been modified for this purpose. As the pellet was delivered, the hopper light remained lit for 4.4 s. In the experimental chambers, water was available from small cups located under the house light.

The experimental chambers and home cages were housed in a closed, light-shielded room. Chamber exhaust fans and a large room fan served to ventilate and shield the birds from extraneous ambient noise.

Scheduling and data collection were programmed via an IBM-PC interfaced with a MED Associates, Inc. 16 port interface, Model DIG-700IBM, with millisecond crystal timer. Data collected during the study was stored by the IBM-PC and subsequently analyzed on the IBM-PC and a Toshiba 1100+ personal computer. Programs for the collection, storage and analysis were written by the experimenter in the ZBASIC programming language, a high-level compiled implementation of BASIC.

The arrangement of the experimental equipment and housing of the subjects is presented in Figure 1.

An 11.5 hr-12.5 hr dark/light cycle was maintained throughout the study, both prior to and during the experiments. During experiments, the birds were placed in the experimental chambers during their 11.5 light periods. During this time, the chambers were illuminated with a 7.5-W light bulb located in the upper-outside-right corner. GE 1819 bulbs, operated at 5 V dc in series with a 150 ohm resistor, illuminated the right and left response keys, according to the conditions scheduled for each. Another GE 1819 bulb, located within the feeder hopper, was illuminated when the hopper was raised or a pellet was delivered, for programmed reinforcement.

During 30 min periods after the termination of an experimental session, the birds were exposed to light in the housing/laboratory area,

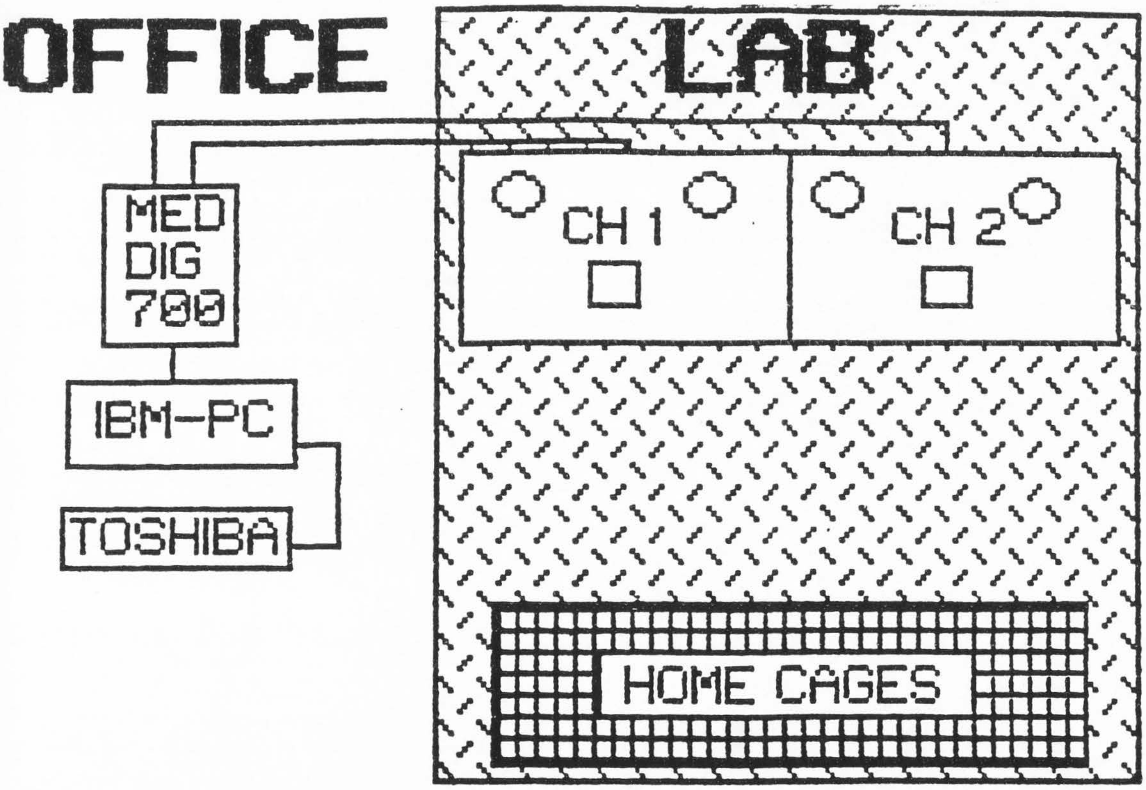


Figure 1. Experimental apparatus and housing arrangement.

during which the chambers and home-cages were maintained. To simplify time references, daily session times were defined with respect to the subject's light/dark cycle. The midpoint of the dark period was designated as the change of day. This procedure enabled the birds to respond without constraint to their diurnal pattern for free-feeding that has been well established (Zeigler, 1976; Zeigler, Green, & Lehrer, 1971).

The birds were housed in 24 x 24 x 24 in. home cages during their dark cycles. Water was provided in the home cages in 8 x 6 x 4 in. tubs that allowed both drinking and bathing on demand. The relatively large size of the home cages permitted ample room for the birds to stretch and flap their wings.

Procedures

Sessions

Eleven and one-half hour sessions were conducted seven days per week over a period of 9 months. During sessions, pecks on the illuminated response key (left for FR1 schedules, and right for VI schedules) were required to complete the schedule requirement. Completion of the requirement simultaneously darkened the response key and illuminated the hopper aperture and made food accessible. The hopper remained illuminated for 4.4 s, after which the hopper was darkened and the response key was again illuminated. This continued until the 11.5 hr session terminated. Thus, no restrictions were placed on the birds regarding the number of reinforcers that could be obtained, nor when they could be obtained, with the exception that all reinforcements had to be obtained by responding according to the scheduled contingencies within the 11.5 hr sessions.

Stability

Throughout the study response stability was determined by establishing a 5 day response mean and determining whether responding on the sixth day fell within 10% above or below this mean. If responding during the sixth day met this criteria, responding was judged to be stable. If it did not, a new 5 day mean was established utilizing the data collected during the previous five days and the present day's data as the sixth day to judge for stability. Given that the data from these sessions represented stable responding, these data were used in all analyses conducted. All figures present data from these stable sessions.

CHAPTER IV

EXPERIMENT I

Purpose

Given the finding that responding in an open-economy is directly related to overall reinforcement rate while that in a closed-economy is inversely related to overall reinforcement rate, Experiment I was performed to determine if this could be demonstrated in one experiment.

Previous investigations on which this finding is based (i.e., Catania & Reynolds, 1968, in the former case; Hursh, 1978, in the latter) have been conducted as separate studies. The purpose and conditions of these experiments were notably different. It is conceivable that the differences they obtained could be attributed to procedural differences between studies. Thus, by conducting Experiment 1, objectives 1 and 2 of the present research program were examined.

Method

Procedures

All four subjects were pretrained so that pecking was maintained by presented schedules. Subsequently, Experiment I was conducted in four phases; each involved a change of conditions.

Condition 1: Weight stabilization on FR1. This condition consisted of presenting each of the subjects with an FR1 schedule of reinforcement, during daily 11.5 hr sessions. Total daily consumption was obtained by responding on this schedule. The condition continued until the weight and FR1 behavior of each bird stabilized. This condition served as the free-feeding baseline that was later used in the open-economy condition of the experiment. The left response key was lit throughout the session. Each key peck produced 4.4 s access to feed through the lit hopper, and simultaneously darkened the response key. Responses during hopper-lifts were recorded, but had no effect on the number or duration of hopper presentations.

Condition 2: Baseline-closed-economy. During this condition, the birds obtained all daily access to food by keypecking on the right response key under various VI schedules of reinforcement. The amount of food obtained was determined by the birds' responding. This condition further exposed the birds to the closed-economy in that access to food was directly related to responding, and there was no access to a substitute source of food.

Table 1 illustrates the VI schedules to which each of the birds was exposed and their presentation sequence. Each VI schedule was presented during successive sessions until responding stabilized.

Once each subject had been exposed to each of the four VI schedules, a reiteration on one of the VI schedules was run with Subjects 1 and 2, and an intermediate VI schedule (VI70) was introduced to Subject 3. This enabled a comparison to determine the reliability of the results.

Table 1

Schedules and Sequence of Introduction

	Presentation Sequence			
Bird	1	2	3	4
1	VI50	VI10	VI30	VI70
2	VI50	VI10	VI30	VI70
3	VI20	VI60	VI40	VI80
4	VI20	VI60	VI40	VI40

Each VI schedule was presented during successive sessions until responding stabilized.

Condition 3: Introduction of open-economy (substitute food). Once the range of predetermined VI schedule values had been presented to the birds, they began receiving 75% of their daily food in the experimental chambers as substitute food, made available for responses on the left response key, utilizing a FR1 schedule of reinforcement. This condition approximated the open-economy procedure of supplying make-up, or substitute, food after each session. Data obtained during Condition 1 (Weight stabilization on FR1), was utilized to determine the number of reinforcers that would be provided as substitute food, based on each subject's free-feeding baseline.

Each session began with the presentation of the programmed VI schedule of reinforcement that continued until the subject had obtained a given percentage of their FR1 baseline number of reinforcers.

Immediately following the delivery of the required number of reinforcements, the right response key darkened and the left response key was illuminated. Reinforcement was then available for responses to the left key on a FR1 schedule of reinforcement. This procedure was considered a close approximation of a typical open-economy. No maximum number of reinforcements were scheduled artificially by the experimenter, and food continued to be available on the FR1 throughout the remainder of the session. Once a bird stabilized on the presented VI schedule, a new schedule was introduced, utilizing the same procedures. That is, the bird was required to obtain a percentage of the free-feeding baseline by responding according to the schedule requirement, after which a FR1 schedule was presented on the left key whereby he could obtain substitute food. This procedure continued until the bird had been exposed to each of four VI schedules. Each bird was presented with the same VI schedules and presentation sequence as in Condition 2. Birds 1 and 2 were provided with 75% substitute food, while Birds 3 and 4 received 50%.

Results

Condition 1: Weight stabilization on FR1. All four birds' weights quickly stabilized on this condition. Table 2 presents the mean weight of each subject and the mean number of reinforcers required to maintain that weight.

Table 2

Mean Weight of Each Subject and Mean

Number of Reinforcements Obtained

Bird	Mean Weight (gms)/ Mean No. Reinforcements Obtained
1	524.20 / 230
2	497.40 / 242
3	411.00 / 269
4	415.00 / 331

The two heaviest birds required fewer reinforcers than the two lightest birds to sustain their weights. In fact, the mean daily consumption of grain by Birds 1, 2, 3, and 4 was 51 gms, 32 gms, 41 gms, and 35 gms, respectively. It should be noted that the mean gram intakes are approximate figures, because it was not always possible to account for 100% of spillage, and the markings on the hopper did not allow for an exact measure. Nonetheless, it is apparent that consummatory efficiency varied from subject to subject.

Condition 2: Baseline-closed-economy. The number of sessions required to obtain stable responding are shown in Table 3.

Table 3

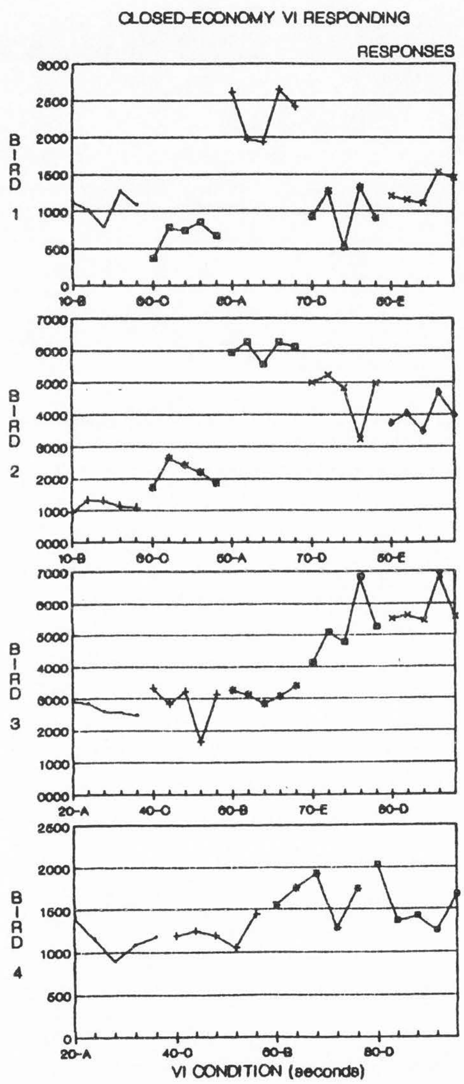
Total Number of Sessions to Stability

for Each VI Schedule

Bird	VI10 s	VI30 s	VI50 s	VI70 s
1	15	13	15	8
2	14	15	14	7
	VI20 s	VI40 s	VI60 s	VI80 s
3	7	8	10	8
4	14	8	9	8

The following figure (Figure 2) presents the results obtained from this condition for each subject. The final five sessions are shown. The sequence of the introduction of each of the schedules is denoted by a letter that follows the schedule along the X-axis of the graph.

The results from this condition were somewhat erratic. An increasing trend in responding had been anticipated, based on the results reported by Hursh (1978, 1980), in spite of the modest procedural differences between these studies. That is, it was predicted that as the schedule requirement increased (i.e., increasing from VI10 to VI70), the total number of responses made per session would also



<u>Figure 2</u>. Total number of responses in VI conditions in a closed-economy. Each graph presents the data from the last 5 sessions per VI condition for each subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

systematically increase. There was evidence of such a trend in the performances of Subjects 3 and 4. In the case of Subject 3, the increases between VI20, VI40 and VI60 were small. It is not until VI70 and VI80 that the differences are marked. Furthermore, the differences between VI70 and VI80 are also small. Response differences between schedules by Bird 4 are small throughout, but increasing and systematic.

Subjects 1 and 2, show no clear or systematic trends. In fact, there is disparate responding between the first introduction of the VI50 schedule of reinforcement and its reiteration. As described below, this can be attributed to variations in consummatory efficiency that can account for between, as well as within, condition variability in the amount of reinforcers obtained.

An examination of the total number of reinforcers obtained by each subject during this condition, and the weights that were maintained by this reinforcement density, served to explain possible causes for these results. These data are presented in the following figures.

As shown in Figure 3, there was considerable variability in the number of reinforcers obtained between VI schedules, across all subjects during their exposure to the closed-economy. Nonetheless, the weight of each subject remained fairly stable throughout the condition. In general, as the number of reinforcers decreased, only small decreases in weight were observed. Paradoxically, in the case of Subject 4, decreases in obtained reinforcers were accompanied by actual increases in weight.

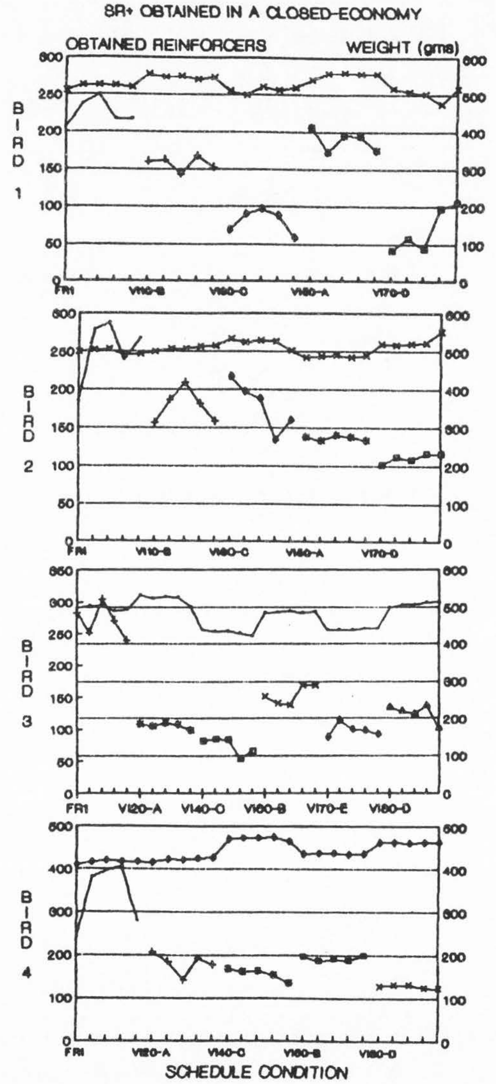


Figure 3. Total number of obtained reinforcers by each subject, presented together with the weights maintained by these reinforcers in a closed-economy. Reinforcers consisted of 4.4 s access to chow.

Taken together, the data obtained from Condition 1 and Condition 2 provided strong evidence that the magnitude of reinforcement was, in fact, not controlled during Experiment I. That is, as the schedule requirement became more restrictive (i.e., average inter-reinforcement intervals increased), eating efficiency must have also increased. As a result, consumption was sensitive to the schedule parameters, but responding was not. Casual observation on a random basis supported this possibility. It appeared as though the subjects kept their heads in the hopper longer during each reinforcement as the schedule requirements increased. Furthermore, at the highest reinforcement density (i.e., VI10 s), the subjects were observed to remove pieces of chow from the hopper and drop them through the grated floor of the chamber during hopper access. This did not happen at longer schedules.

Condition 3: Introduction of an open economy-substitute food. The conclusions from Conditions 1 and 2 were supported by the results from Condition 3, in which the subjects were exposed to an open-economy (responding on VI schedules for 25% or 50%) of daily reinforcers and then presented with an FR1 schedule, on which the subjects were free to respond throughout the remainder of the session. These results are presented in Figure 4. Despite being exposed to the same VI schedules as in the previous condition, responding in these two conditions varied, but in no systematic way. For example, in Condition 3, Bird 2 showed an increasing response trend from higher to lower reinforcement densities, while in Condition 2, no such trend was evident. Just the opposite was the case for Bird 3.

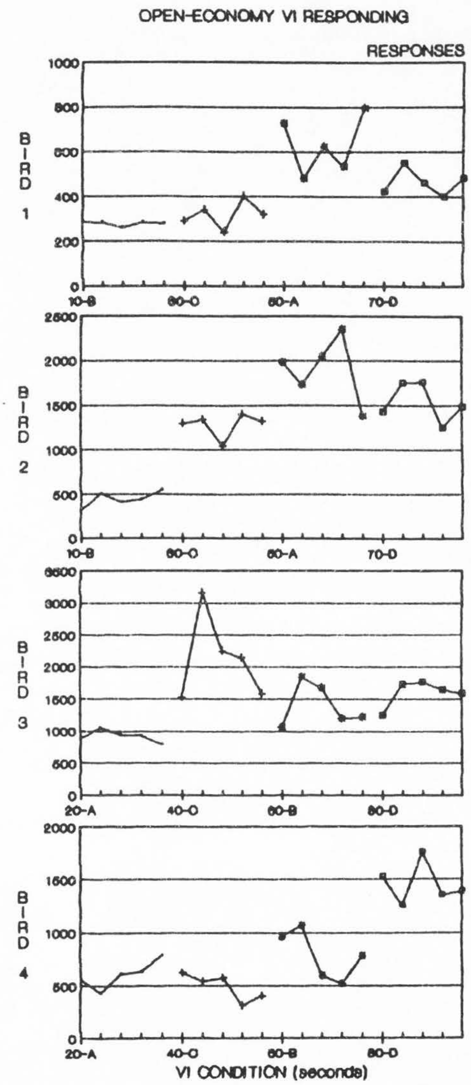


Figure 4. Total number of responses on VI schedules in an open-economy. A percentage of daily reinforcers were obtained for responding on VI the schedules of reinforcement. The remaining reinforcers were obtained by responding on a FR1. Each graph presents the data from the last five sessions per VI condition for a subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

Across the conditions of this experiment, monitoring consumption showed that increases or decreases in reinforcers obtained by the subjects had little effect on the actual amount of food consumed. As the schedules restricted the opportunity for reinforcement, the subjects ate more efficiently at each reinforcement. In this way, they were able to maintain their weight despite fewer food presentations.

Thus, it appears reinforcement magnitude was inadequately controlled in this and, perhaps, many other experiments. That is, responding alone did not control the amount of reward actually obtained. Clearly, this finding confounds an analysis of the relation between responding and reinforcement schedule such as is needed here to compare open- and closed-economies. Without controlling reinforcer density, it is not possible to determine whether manipulating the proportion of reinforcers provided as supplemental food controls the relation between responding and reinforcement in open- and closed-economies.

With reward density controlled, Experiment II was conducted.

CHAPTER V

EXPERIMENT II

Method

Purpose

Experiment II was conducted as a systematic replication and extension of Experiment I. The primary objectives of the experiment were: (1) to determine whether responding in an open-economy was directly related to overall reinforcement rate, while that in a closed-economy was inversely related to overall reinforcement rate; and, (2) to determine whether the response-to-reinforcement correlation was controlled by the amount of substitute food provided in open-economies. In addition, the experiment was designed to suggest an apparently more appropriate methodology for operant research on the distinction between open- and closed-economies than has heretofore been employed.

It was assumed that open- and closed-economies do not represent two opposing alternatives, but rather that they are two parametric extremes on a continuum. This possibility has been suggested by the results of experiments conducted by Catania and Reynolds (1968), Hursh (1978, 1986), and Lucas (1981). If this is, indeed, the case, then increasing the amount of daily food provided as a substitute commodity will induce the response-to-reinforcement relation to shift from a closed-economy type to an open-economy type.

Subjects

The same subjects as those employed in Experiment I were used in this experiment.

Apparatus

To correct the difficulty encountered in Experiment I and attributed to insufficient control over reinforcement magnitude, the grain hoppers were replaced with pellet dispensers. These Davis pellet dispensers can be pulsed such that they would deliver one 45 mg precision pigeon pellet (Bioserv) when reinforcement was signaled. These pellets are made of a balanced mix of nutrients so as to be an adequate diet, 100% nutritionally complete, and in accordance with the National Research Council standards for pigeons (Bio-Serve, 1988).

Procedures

Experiment II consisted of three conditions. Through Condition 1, the subjects were exposed to a closed-economy. All daily food consumed was obtained by responding according to various VI schedules of reinforcement. In Conditions 2 and 3, in which the subjects were exposed to open-economies, subjects began each session by being presented with a VI schedule programmed on the right-hand response key. By responding on this key, the subjects obtained a percentage of the total number of reinforcers that was estimated they would obtain during that session. The percentages differed between the two conditions. In Condition 2, subjects were required to obtain 25% of their total number of daily reinforcers by responding on the VI schedule, while in Condition 3, subjects were required to obtain 75% of their total daily consumption this way. These percentages were selected as simple arithmetic proportions of the subjects' daily consumption between a totally open- (approximately 100% substitute food), and a totally closed-economy (0% substitute food).

The actual number of reinforcers that constituted the daily percentage to be obtained during the VI component of the session was based on the total reinforcers earned the previous day. For example, in Condition 2, if on day X a subject obtained a total of 400 reinforcers (combined number of reinforcers obtained during both the VI and FR components of the session), the next day that subject would be exposed to a VI schedule until it had obtained 100 reinforcers. During the subsequent FR component of the session there was no restriction placed on the number of reinforcers that could be obtained during the time remaining in the 11.5 hr session. In this way the number of reinforcers obtained for responding, when exposed to the VI schedule, varied from subject to subject and from day to day. This procedure was employed to account for the day-to-day fluctuations in food requirements of the subjects (Zeigler, 1976).

To avoid chain effects, an 8 min change over delay (COD) (Honig, 1965) between variable-interval and fixed-ratio components of the sessions was employed throughout. That is, when the VI component of the session ended, all stimulus lights in the chamber were darkened for 8 min. Then, the lef- hand stimulus light was turned on, signaling the onset of the FR component of the session.

To ensure that results from the experiment could not be attributed to sequence effects, Birds 1 and 2 were presented with Condition 3 prior to Condition 2, while Birds 3 and 4 were presented with Condition 2 prior to Condition 3.

Conditions 2 and 3 closely approximate the open-economic condition of standard operant experiments. In these experiments, subjects typically earn a portion of their total daily food consumption during the experimental session. Once the session ends, the subjects experience a brief feeding delay, while they are moved to their home cages, where they are provided with substitute, response-independent food.

Despite the similarity between the procedures used in the present experiment and those employed in the typical operant experiment, the present procedures vary in three ways. First, in typical operant experiments, subjects are food deprived and maintained at an artificial weight that is below their free-feeding weight. The procedures used here involved no experimenter-induced deprivation, nor were subjects' weights artificially maintained.

Second, in typical operant experiments, session lengths are relatively short, rarely exceeding more than several hours in duration. Most are generally less than 60 min long. Session lengths throughout this experiment were 11.5 hrs, which permitted feeding without restricting the diurnal feeding patterns of the pigeon subjects (Zeigler, 1976).

Finally, in typical operant experiments, substitute food is provided to the subjects in their home cages in small receptacles that minimize the cost of consumption. A feeding bout is not restricted in any way until the available substitute food is completely consumed. In Conditions 2 and 3 of the present experiment, substitute food was provided in the experimental chamber for responding according to a FR1 schedule. Each response was reinforced with one 45 mg precision pigeon pellet. No restriction was placed on the number of pellets that could be obtained during the FR1 components of the session. This response requirement procedure permitted the consumption of substitute food to be reliably measured. While different from the typical operant experimental procedure, it is not inconsistent with food intake in the wild, where there is always, albeit small at times, response cost for food (C. D. Cheney, personal communication, December 16, 1986).

Overall, the procedures used here permit examination of the dependent measures (responding, reinforcement, and weight) through the manipulation of the independent measures (VI schedules and amount of substitute food provided), with little concern for variables extraneous to the objectives of the research (levels of deprivation and session length). The procedural differences between the typical operant experiment and the present experiment may somewhat restrict the generality of the findings.

Condition 1: Closed-economy. In this condition, all birds acquired 100% of their daily food intake by responding under various VI schedules of reinforcement. The birds were exposed to a closed-economy in that no access to substitute food was available, and all food pellets obtained were VI response-dependent.

The birds were exposed to the same VI schedules of reinforcement in the same presentation sequence as in Condition 2 of Experiment I (see Table 1).

Condition 2: Introduction of an open-economy. In this condition, subjects obtained 75% of their total daily intake as substitute (FR1) food. Thus, as the subjects began each session, they were first presented with a VI schedule, programmed on the right-hand response key. When the subject had acquired 25% of the total number of reinforcers obtained during the previous session, the active response key was darkened. This was followed by an 8 min COD, after which the left-hand response key was lighted. Responses on this key were then reinforced, according to a FR1 schedule of reinforcement. Throughout the remainder of the session, food pellets were available without restriction, other than the single response required on the left-hand response key.

This condition represents the extreme open-economy condition of this experiment and closely approximates the typical operant experiment where only a portion of total daily consumption is obtained during the experimental session.

All subjects were exposed to the same VI schedules and in the same sequence as presented in Table 1.

<u>Condition 3: Alternate open-economy</u>. Subjects were provided with 25% of their total daily intake as substitute (FR1) food in this condition. Therefore, as the subjects began a session, they were required to obtain 75% of their daily food by responding on the right-hand response key according to a VI schedule. Once accomplished, the right-hand response key darkened and an 8 min COD followed. Subsequently, substitute food was provided for responses on the left-hand response key according to an FR1 schedule, throughout the remainder of the session. As in Condition 2, the percentage to be earned during the VI component of the session was determined utilizing the total number of reinforcers obtained the previous day. All subjects were

exposed to the same VI schedules and in the same sequence as presented in Table 1.

The open-economy utilized in this condition was designed to more closely approximate closed-economy conditions than those presented in Condition 2. Thus, by comparing results from these three conditions, the possibility that closed- and open-economies represent two extremes along a continuum could be examined.

Results

To assess the effects of the manipulation of the independent measures (schedule and economic condition) on the dependent measures (responding, reinforcement and weight), several analyses were conducted on the data from all conditions. First, to determine effects on responding, response rates were assessed using the following formula:

$$\text{Response Rate} = \frac{\text{Total Responses}}{\text{Running Time}}$$

where Response Rate represents responses-per-minute, Total Responses represents the total number of responses made during the session, and Running Time represents total number of session minutes during which the subject was responding. Running time was calculated by establishing 138 consecutive 5 min cells, representing an 11.5 hr session. Responses were then distributed among the cells according to the session time that each occurred, and cells without responses were eliminated. This removed the time between feeding bouts from the analysis.

Second, to determine effects on reinforcement, the total number of reinforcers obtained by the subject during each session was calculated.

Third, effects of manipulations on weight were made by determining pre- and post-session weights of the subjects.

All data presented were obtained from the VI components of the last five sessions of each schedule introduced. To assist the clarity of the presentation, the results obtained with each subject in each of the three conditions of the experiment are presented separately.

Bird 1

Condition 1: Closed-economy. In this totally closed-economy, with reinforcement magnitude controlled, the subject obtained 100% of its daily food allotment by responding according to four VI schedules presented in the following order: VI50 s, VI10 s, VI30 s and VI70 s. Figure 5 presents the effects of these schedules on the response rate of Bird 1 in this closed-economic condition, as well as in an open-economy, where 75% of total daily food was provided as substitute food.

Based on visual inspection of the results, it is clear that responding was, in general, inversely related to overall reinforcement rate in the closed-economy condition. This relation is nearly linear through the three lowest VI schedules. However, at VI70 s, response rate decreased dramatically. Hursh (1978) reported a similar effect in a closed-economy experiment conducted with monkeys. In his experiment, a steady increase in the rate of responding was observed as the VI schedule increased from 20 s to 50 s, and the corresponding rates of reinforcement decreased. However, at VI schedules greater than 50 s, response rate began to decline.

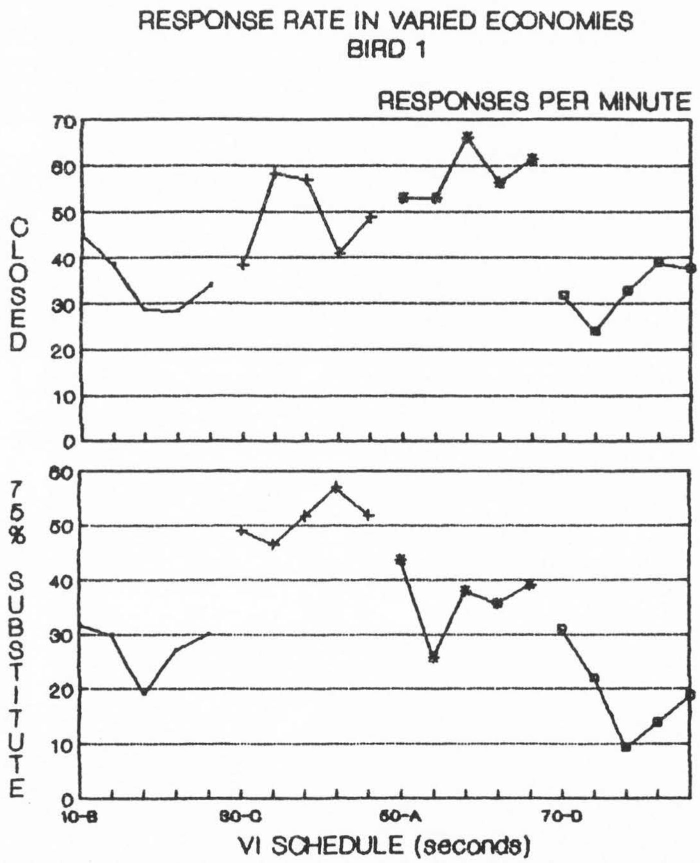


Figure 5. Response rate of Bird 1 in varied economies. The data from the last five sessions per schedule are shown. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

Daily fluctuations in response rate are observable at all schedule values. This may be due to the stability criteria applied for determining when changes in schedule conditions should be made. Stability was determined by establishing a 5 day mean of the total number or responses made per session. When the total number of session responses on the sixth day fell within 10% of the 5 day mean, responding was judged to be stable, and conditions were changed. This measure of stability is related to response rate; as total number of session responses increases, so does response rate. However, this relation is not on the magnitude of a one-to-one correspondence. That is, a 5% increase in total session responses does not necessarily reflect a 5% increase in response rate. Thus, larger between-session differences in response rate may be accompanied by smaller between-session differences in the total number of responses made. Despite these daily fluctuations in response rate the increasing trend is clearly observable.

In Figure 6, the total number of reinforcers obtained by Bird 1 as a function of responding, according to the schedules presented, and the accompanying effect on its weight, are displayed for the closed- as well as open-economy conditions of this experiment.

As the VI schedule increased in the closed-economy condition, the number of reinforcers obtained decreased. This decrease in obtained reinforcement was accompanied by a decrease in the subject's weight. Furthermore, at the higher reinforcement densities (i.e., lower VI values), there were greater pre- and post-session weight differences than at the lower reinforcement densities. It is important to recall

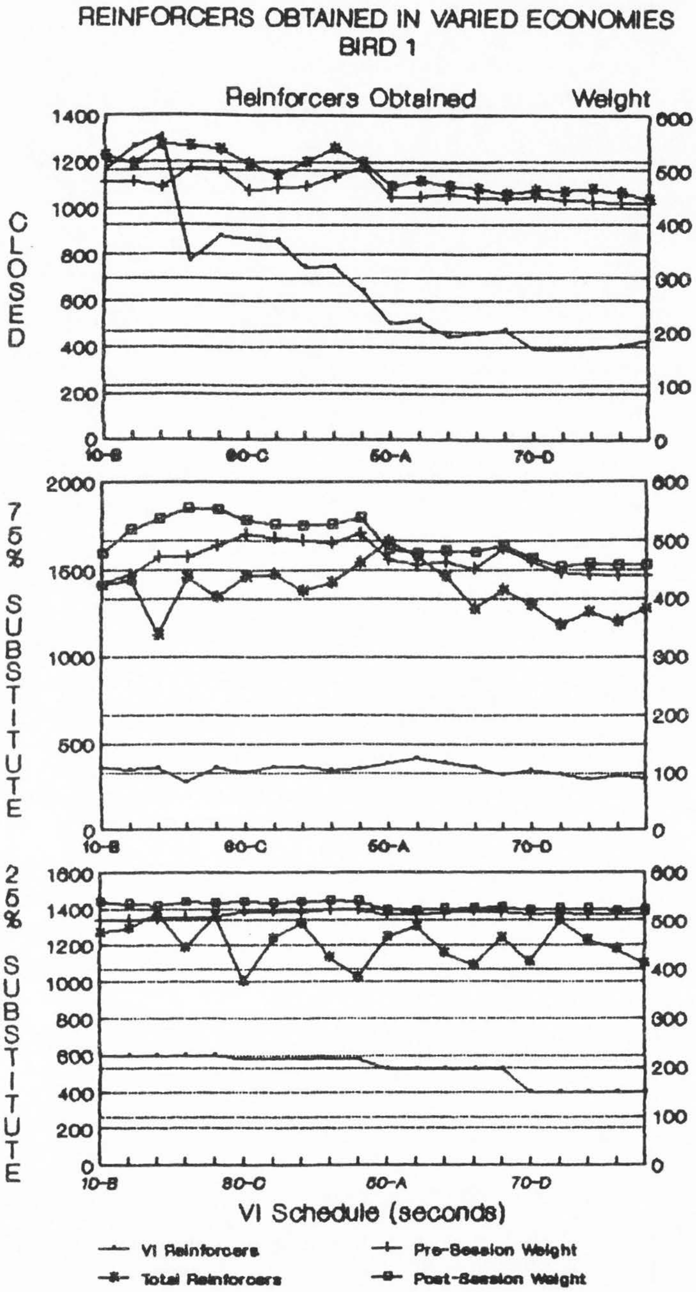


Figure 6. Reinforcers obtained by Bird 1 in varied economies. Data presented are from the last five sessions of each VI schedule presented. The total number of reinforcers obtained during the 11.5 hr session is presented together with the pre- and post-session weight (grams) of the subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

that the subjects were not deprived, other than the deprivation imposed by the 12.5 hrs between sessions.

When the response rate, obtained reinforcers, and weight data are considered together, it appears that when Bird 1 was presented with VI schedules which produced high reinforcement densities (i.e., VI10 s), it maintained a low rate of responding and consumed more food than required to maintain its weight. However, as the reinforcement density decreased, response rate increased, and excess consumption decreased. Despite the increase in response rate, both obtained reinforcers and weight decreased in the presence of this challenge. At the lowest reinforcement density, all three dependent measures (response rate, obtained reinforcers, and weight) decreased. At this point, Bird 1's weight represented approximately 80% of that maintained at the higher reinforcement densities.

Condition 2: Open-economy (75% substitute food). This open-economy condition began with the presentation of a VI schedule of reinforcement. Responding according to the schedule provided the subject with 25% of the total number of reinforcers obtained during the previous session. Once this requirement was met, additional reinforcement was available for responding according to a FR1 schedule throughout the remainder of the session. This condition represented the extreme open-economy of this experiment. The subject was exposed to the same VI schedules in this condition as in the previous condition. The effects of this condition on response rate are presented in Figure 5.

In this open-economy in which 75% of total daily reinforcement was provided by an alternative source of food (i.e., FR1 as opposed to VI schedule), responding was generally directly related to overall rate of reinforcement. That is, as the reinforcement density decreased, so did the subject's rate of responding. The relation is observed as a linear decrease in response rate as the VI schedule value increased from 30 s to 70 s.

Bird 1's rate of responding at VI10 s is discrepant with that of the three other schedule values tested. Yet, when Bird 1's response rate on this schedule is compared with his response rate on the same schedule in the closed-economy condition (see Figure 5), it is clear that both are approximately equal. Thus, there is little observable difference between VI10 s responding in these two conditions.

An examination of the effects of the present condition on Bird 1's weight and the number of reinforcers obtained (Figure 6), suggests that, in this condition as well, the subject obtained a greater number of reinforcers than necessary to maintain weight when responding according to the VI10 s schedule. Particularly at this schedule, there was a greater discrepancy between pre- and post-session weights. This large discrepancy is not observed at the VI30 s, VI50 s, or VI70 s schedules. As the value of the VI schedule increases from 10 s to 70 s the subject's weight slowly declines, as was the case in the closed-economy condition (see Figure 6). Notwithstanding, this decrease is smaller in magnitude. It is also notable that the subject maintained a slightly higher weight throughout this condition than that maintained during the closed-economy condition.

The number of reinforcers obtained during the VI component of the sessions remained stable throughout the condition. However, there were daily fluctuations in the total number of reinforcers obtained during the sessions, both within- and between-schedules. The within-schedule fluctuations were small enough that they did not have a large effect on the number of reinforcers required in the VI component of subsequent sessions. Such an effect is only observed in the total number of reinforcers obtained on day 3 of the VI10 s stability sessions. In this case, the total number of reinforcers obtained drops considerably from the previous day's total such that the number of reinforcers required to terminate the VI component on day 4 also decreased considerably. Generally, the total daily obtained reinforcers increased throughout the VI10 s and VI30 s schedules. At the VI50 s schedule, the total number of reinforcers obtained declined, with an accompanying decline in weight. Both weight and number of reinforcers obtained remained rather stable throughout the VI70 s schedule.

It is also of note that in this condition, whereby the subject was required to work for only a small portion of its daily reinforcement, it maintained a slightly higher weight at each of the schedules presented than that maintained in the closed-economy condition. The differences are most observable at lower reinforcement densities.

Condition 3: Open-economy (25% substitute food). As in the previous condition, the sessions in this condition began with the presentation of VI schedules of reinforcement, whereby the subject was required to obtain a percentage of the total number of reinforcers acquired during the previous session. After this, additional reinforcement was available for responses according to an FR1 schedule of reinforcement. However, in this condition, the percentage required during the VI component of the session was 75. That is, the subject obtained 25% of the daily food consumed as a substitute commodity. This condition represented the intermediate open-economic condition of this experiment. The subject was exposed to the same VI schedules as in the previous conditions of this experiment.

When Bird 1 was introduced to Condition 3,its responding and resultant food consumption began to cycle. That is, by the sixth day of the condition, the subject was consistently obtaining few reinforcers one day, and obtaining many more reinforcers the next. On high-consumption days, the subject obtained as many as 2,169 45 mg pellets, and as few as 211 on low consumption days. This occurred as a result of the original procedure employed to determine the number of reinforcers to be earned during the VI component of the session.

Specifically, the number of reinforcers to be earned during the VI component for a session was determined by computing 75% of the total number of reinforcers obtained during the previous session. Thus, if during the previous session the subject obtained a total of 1,000 reinforcers, it would continue in the VI component of the present session until it had obtained 750 reinforcers. In the case of Bird 1, this procedure resulted in failure to complete the VI component of the session one day, consequently earning a small total number of reinforcers (i.e., 200). The next day, the VI component would continue only until the subject had obtained a small number of reinforcers. Continuing, Bird 1 would need obtain only 150 reinforcers to terminate the VI component of the session. With the VI component completed, the subject consumed many reinforcers during the FR1 component of that session (i.e., 2,000). Again the next day, in order to terminate the VI component of the session, the subject would have had to obtain 1,500 reinforcers. Rather than complete the VI component, however, the subject would again obtain only a small number of reinforcers (i.e., 200). In this way the cycling continued.

This phenomena continued for 16 sessions until the experimenter intervened. The subject was placed on an FR1 schedule for five consecutive 11.5 hr daily sessions. This stabilized consumption and weight. Thereafter, throughout the remainder of Condition 3, a maximum number of reinforcers that was required to complete the VI component of each session was imposed. This maximum was calculated by determining the mean number of reinforcers the subject earned for each of the VI schedules employed during the closed-economy (Condition 1) of the present experiment. The exact maximum for each schedule is presented in Table 4.

Table 4

Maximum Reinforcers Obtainable by Bird 1 for Each VI Schedule

	VI10s	VI30s	VI50s	VI70s
No. of Reinforcers Obtainable	600	581	525	400

Consequently, the number of reinforcers Bird 1 was required to obtain during the VI component of each session during this condition was stable. This manipulation terminated the subject's cycling. All results presented for Bird 1 in this condition exclude the data from the sessions during which the subject cycled.

However, the manipulation to terminate the cycling on the number of reinforcers obtained by Bird 1 produced results that may invalidate the use of the data to determine the effects of the condition on the relation between responding and overall rate of reinforcement in this intermediate open-economy. The number of reinforcers obtained during the VI component of each session was manipulated by the experimenter, independent of the total number of reinforcers obtained during the entire session. Thus, this total was free to vary from session to session without effecting the number of reinforcers that had to be obtained to terminate the VI component of the session.

The effects of this manipulation are illustrated in Figure 6, 25% Substitute. With the number of reinforcers to be obtained by the subject during the VI component of the session held constant at each schedule, the total number of reinforcers during each session by Bird 1 varied remarkably from session to session. However, this total remained somewhat stable across the condition. This is in contrast with the results obtained in the other conditions of this experiment with this subject, in which the within-schedule number of reinforcers obtained remained stable and a greater variance was observed between-schedules.

The proportion of total daily reinforcement constituted by that obtained during the VI component of the sessions varied considerably in this condition. At higher reinforcement densities (i.e., VI10 s and VI30 s), the number of reinforcers obtained by responding according to the VI schedule represented approximately 50% of total daily consumption. At lower reinforcement densities (i.e., VI50 s and VI70 s), total reinforcers obtained during the VI component of the sessions represented as little as 25% of the total obtained during the session. Again, this is in sharp contrast with the results obtained from the other conditions of this experiment with this subject.

Bird 2

Condition 1: Closed-economy. When presented with this closed-economy condition in which 100% of total daily reinforcement was obtained by responding according to VI schedules of reinforcement, this subject's response rate was inversely related to overall rate of reinforcement. Figure 7 reveals that as the overall rate of reinforcement decreased as a function of increases in the mean interval between reinforcements, the rate of responding increased in the closed-economy condition. This increase is observable across all four VI schedules presented: VI10 s, VI30 s, VI50 s, and VI70 s. The increasing relation between the schedule presented and response rate is negatively accelerated.

When the increasing response rate in the presence of the increasing VI schedules is examined in relation to the number of reinforcers obtained, it is clear that as the VI schedule increased, the total number of reinforcers decreased. These results are depicted in Figure 8.

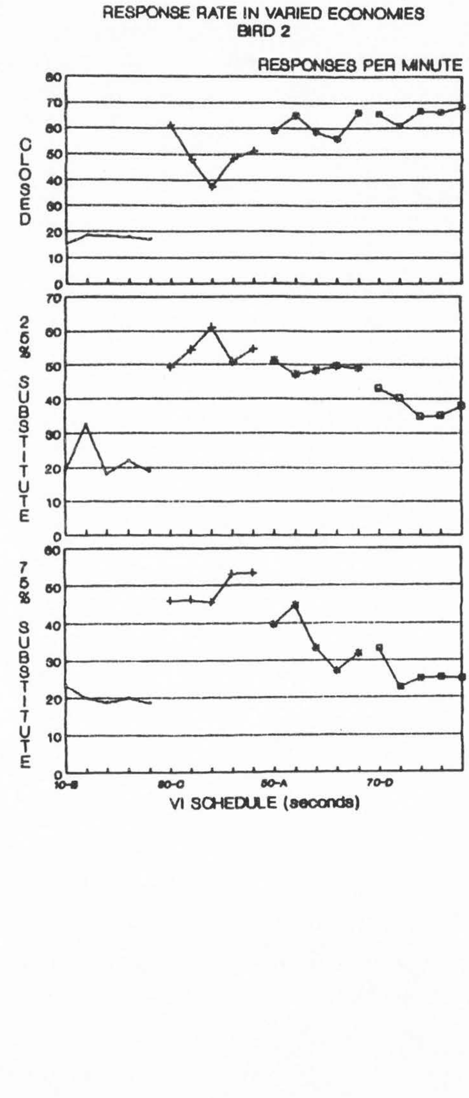


Figure 7. Response rate of Bird 2 in varied economies. The data from the last five sessions per schedule are shown. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

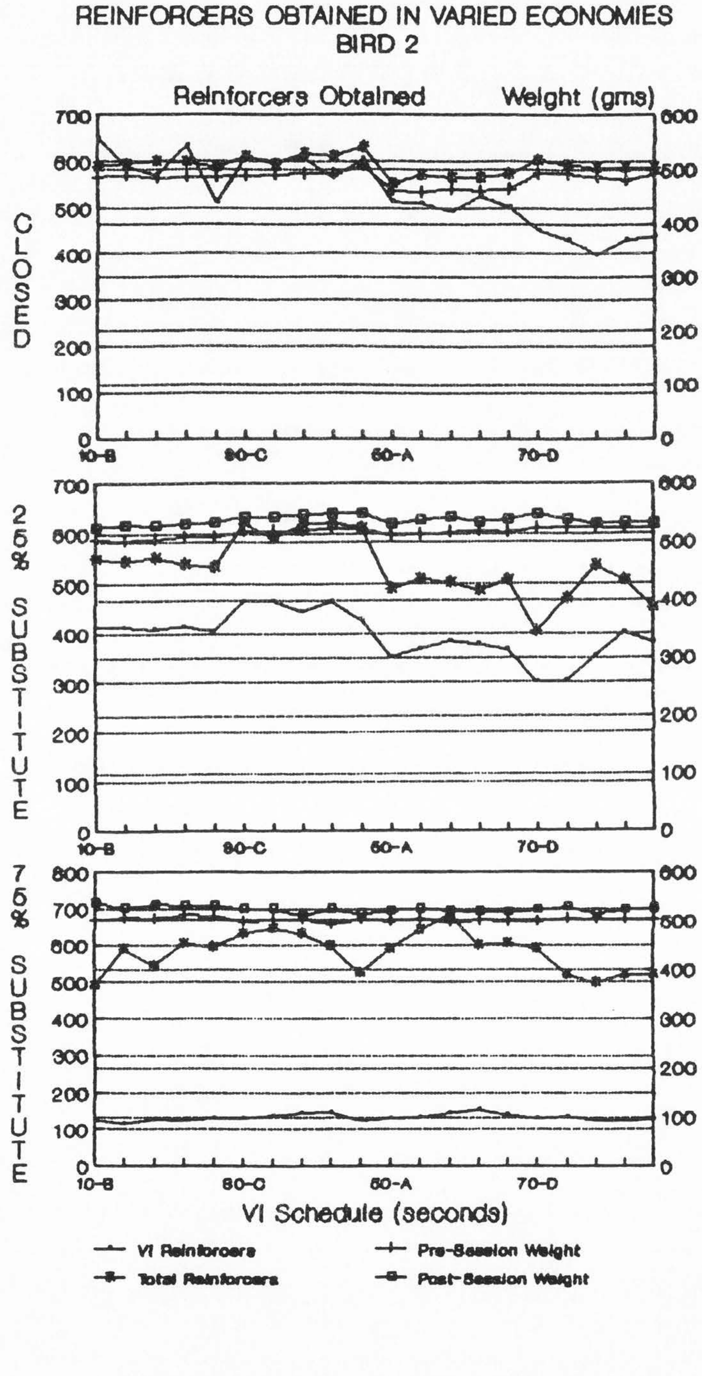


Figure 8. Reinforcers obtained by Bird 2 in varied economies. Data presented are from the last five sessions of each VI schedule presented. The total number of reinforcers obtained during the 11.5 hr session is presented together with the pre- and post-session weight (grams) of the subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

Through the VI10 s and VI30 s schedules, Bird 2 obtained a relatively stable, high number of reinforcers across sessions. However, at the schedules that produced lower reinforcement densities (i.e., VI50 s and VI70 s), the overall number of reinforcers obtained decreased. Comparing the closed-economy data presented in Figure 7 with that presented in Figure 8 shows that despite increases in response rate in the presence of increasing challenge, the negative acceleration of the response-rate increases across schedules produced fewer total reinforcements per session. That is, the decrease in total number of reinforcers obtained as the VI schedule increased from VI10 s to VI70 s was positively decelerated. These results were obtained by presenting the four VI schedules in this sequence: VI50 s, VI10 s, VI30 s, and VI70 s.

Figure 8 also shows that Bird 2's weight remained stable throughout this closed-economy condition. Despite the decrease in the total number of reinforcements obtained at the higher VI schedules, the subject's mean weight was little effected. Only at VI50 s did the subject's weight decrease; however, this decrease was less than 10% of the mean weight of the subject across the experiment. Furthermore, the mean weight of the subject was recuperated on the VI70 s schedule, when the total number of reinforcers obtained was lowest. However, smaller differences between pre- and post-session weights are observable at higher VI schedules.

<u>Condition 2: Open-economy (75% substitute food)</u>. In this open-economy condition, where 25% of total daily food consumption was accomplished by responding according to VI schedules of reinforcement,

and the remainder was supplied from an alternate food source according to an FR1 schedule, Bird 2's response rate was generally directly related to overall rate of reinforcement. These results are presented in Figure 7.

With the exception of the response rate on the VI10 s schedule, as the reinforcement density decreased, so did the subject's response rate: a direct relation. In fact, at the lowest rate of reinforcement, on the VI70 s schedule, the response rate was approximately 50% of that on the VI30 s schedule.

The lowest response rate obtained was produced by the subject's responding on the VI10 s schedule. This is in contrast with Bird 2's responding on the other schedules. However, the response rate on VI10 s in this condition is the same as that on the VI10 s schedule in the closed-economy condition: approximately 20 responses per reinforcer (see Figure 7).

Figure 8 illustrates the effects of this condition on the total number of reinforcers obtained by Bird 2 and its weight. In this condition, the subject's weight remains stable throughout, and there is little pre- and post-session weight variance between and across schedules. Despite fluctuations in the total number of reinforcers obtained between schedules, variability within schedules is small.

With relatively small differences in the total number of reinforcers obtained across sessions and schedules, there are even smaller between-session and between-schedule differences in the number of reinforcers obtained during the VI components of the sessions. This is due to the fact that the number of reinforcers that had to be obtained in order to terminate the VI component of the sessions was linked directly to the total number of reinforcers obtained during prior sessions. Small between-session differences in total daily-obtained reinforcers produced even smaller between-session differences in obtained reinforcers during the VI component of the sessions.

Condition 3: Open-economy (25% substitute food). In this intermediate open-economy, the subject obtained 75% of its daily reinforcement by responding according to various VI schedules of reinforcement. The balance of the daily consumption was supplied as substitute from an alternate source, for responses on an FR1 schedule. In general, Bird 2's response rate in this condition was directly related to overall rate of reinforcement. This relation is depicted in Figure 7.

As the overall rate of reinforcement decreased as a function of increases in mean schedule interval, the response rate generally decreased in a direct relation. Only at the VI10 s schedule were the results of this condition inconsistent. However, this finding is consistent with the results obtained in Conditions 1 and 2 of this experiment as regards response rate on the VI10 s schedule with this subject. That is, there is little difference in mean response rate on this schedule across conditions.

The decrease in response rate across the VI30 s, VI50 s, and the VI70 s schedules is less pronounced than that observed in Condition 2 with this subject. Also, the subject maintained slightly higher response rates on these three schedules in the present condition than in Condition 2, the extreme open-economy.

The relatively small between-schedule differences in response rate were accompanied by similar differences in the between-schedule total number of reinforcers obtained. However, the within-schedule total number of reinforcers obtained was stable, with only a slight exception on the VI70 s schedule. These data are presented in Figure 8.

Despite the differences in the total reinforcers obtained across schedules, Bird 2's weight remained stable throughout the condition. When presented with the VI70 s schedule, there is a smaller discrepancy between pre- and post-session weights than that observed at the other three schedules presented.

It is important to note that when this condition was initiated, Bird 2 cycled in much the same way as Bird 1 in this same condition. However, this cycling continued for only the first five sessions of the condition and then terminated without any intervention or manipulation by the experimenter.

Bird 3

Condition 1: Closed-economy. In this condition, Bird 3 was exposed to four VI schedules of reinforcement in the following sequence: VI40 s, VI60 s, VI20 s, and VI80 s. The rate of responding by Bird 3 in this closed-economy was neither in direct, nor inverse, relation to overall rate of reinforcement. As illustrated in Figure 9, there was some inconsistency in session-to-session response rates within-schedules in the closed-economy condition, giving an appearance of disorder in responding. However, across the entire condition, response rate remained considerably stable. The mean response rate for the condition

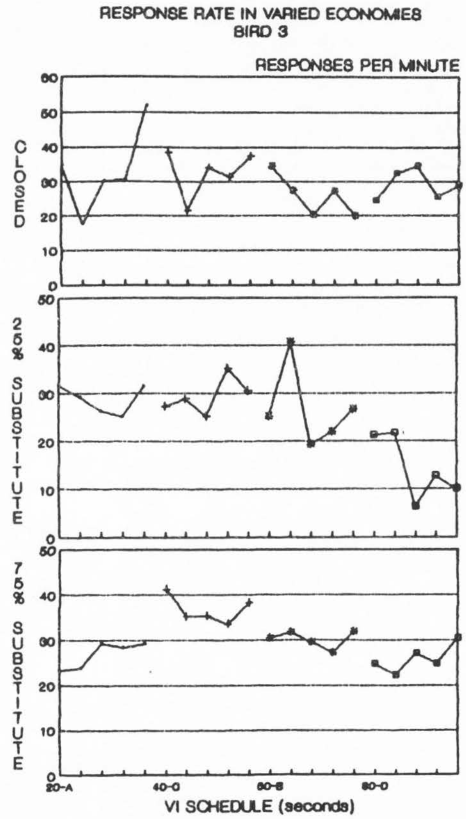


Figure 9. Response rate of Bird 3 in a closed-economy. The data from the last five sessions per schedule are shown. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

was 30 responses per min. The mean response rate for the four schedules, VI20 s, VI40 s, VI60 s, and VI80 s, were 33.2, 32.2, 26.4, and 29.4, respectively. As the mean VI length increased from 10 s to 80 s, the differences within schedule, but across sessions, decreased. The range in response rate on the VI20 s schedule was 35, 16 on the VI40 s, 15 on the VI60 s, and 10 on the VI80 s.

Notwithstanding the semblance in responding throughout the condition, the total number of reinforcers obtained decelerated as the reinforcement density decreased. This effect is illustrated in Figure 10. The subject maintained a relatively high rate of reinforcement on the lower VI schedules. However, at the highest VI schedule, VI80 s, obtained reinforcers represented approximately 50% of that obtained on the VI20 s.

Although obtained reinforcers decreased dramatically across the condition, Bird 3 maintained a stable weight. Though weight remained stable, the subject's pre- and post-session weight discrepancies faded as the daily obtained reinforcers decreased. Anecdotal records suggest that Bird 3 maintained lower activity levels between sessions, and that there was less excrement in both the experimental and home chambers while exposed to higher VI schedules. For example, Bird 3 was frequently observed to fly in the home chamber during the daily cage maintenance period. Given the size of the home cage, it was possible for the subjects to flap their wings without constraint. In the case of all subjects, they frequently flapped continuously for several seconds. In the case of Birds 1 and 3 however, they were occasionally observed to lift off the floor of the home cage and hover for a few seconds. At

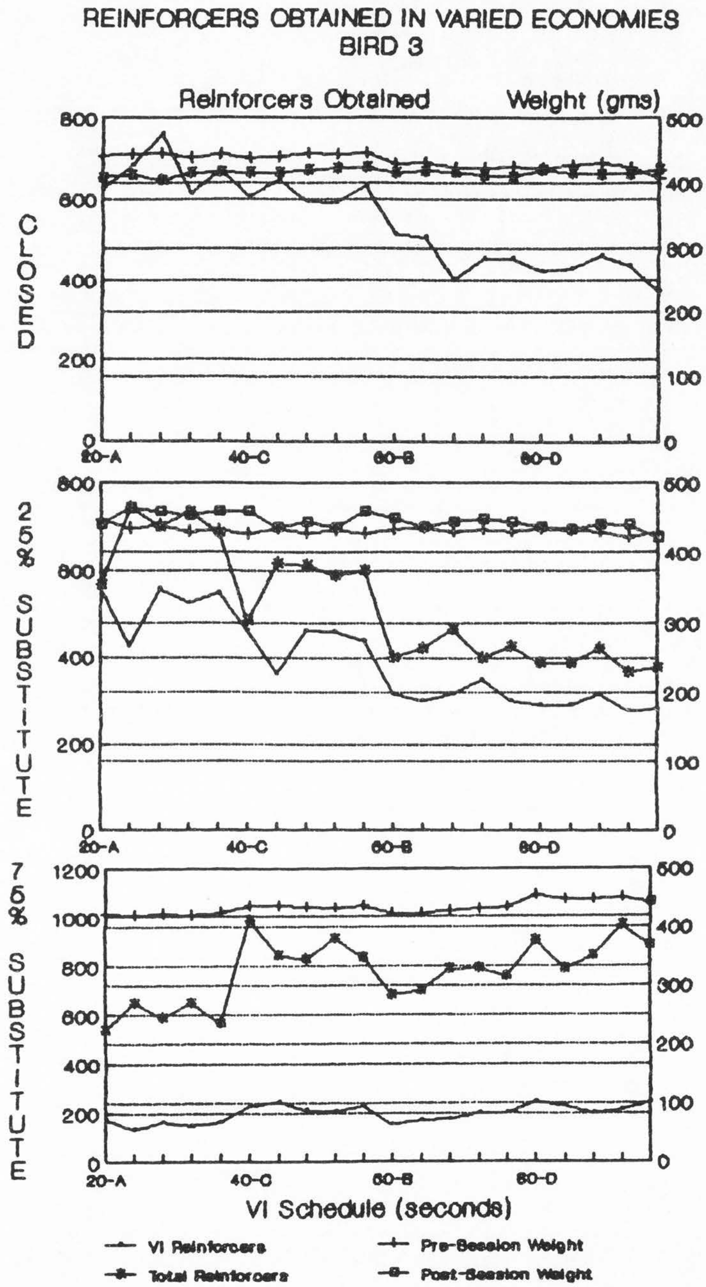


Figure 10. Reinforcers obtained by Bird 3 in varied economies. Data presented are from the last five sessions of each VI schedule presented. The total number of reinforcers obtained during the 11.5 hr session is presented together with the pre- and post-session weight (grams) of the subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

higher VI schedules where total daily reinforcers decreased, such flapping and hovering were not observed. Thus, it appears Bird 3 could have been conserving its weight by reducing energy output as reinforcement density decreased in this closed-economy.

Condition 2: Open-economy (75% substitute food). In this condition, Bird 3 obtained 25% of its total daily reinforcement by responding according to four VI schedules. The remainder of the food consumed during the 11.5 hr session was supplied by responding, according to an FR1 schedule, on an alternate key. The schedules and sequence of presentation were the same as those presented in Condition 1.

The results acquired from this condition are representative of a direct relation between rate of responding and overall rate of reinforcement, as illustrated in Figure 9. With the exception of responding on the VI20 s schedule, as the overall rate of reinforcement decreased, so did the response rate. This observation is consistent through the VI40 s, VI60 s, and VI80 s. The response rate obtained on the VI20 s is discrepant with that of the other schedules. However the rate obtained on this schedule of this condition approximates that obtained on the same schedule in Condition 1 with this subject.

The effects of the response rates on the reinforcement obtained during this condition are displayed in Figure 10. Within-schedule obtained reinforcers are relatively stable. However, across schedules there is an increase in obtained reinforcers as the VI schedule increases. Despite the differences in obtained reinforcers from schedule to schedule, little effect is exerted on the number of reinforcers obtained during the VI components of the sessions, both within- and between-schedules. Thus, the increases in the number of reinforcers required to shift from the VI components of the sessions to the FR1 components is small. The result is that the number of reinforcers obtained during the VI components of the sessions is fairly stable at all schedules presented during the condition.

It is clear that the general upward trend in the total number of reinforcers obtained accompanying increases in VI schedules, is associated with a small, but observable upward trend in the subject's weight. Furthermore, as in Condition 1, pre- and post-session weight differences are negligible at the higher VI schedules, and larger as the VI schedule decreases to VI20 s.

Condition 3: Open-economy (25% substitute food). This intermediate economic condition, in which the subject acquired the majority (i.e., 75%) of its daily food by responding according to VI schedules of reinforcement, before obtaining substitute food by responding on an FR1 schedule, produced a direct relation between response rate and overall rate of reinforcement. That is, as reinforcement density decreased, the response rate also decreased. As is observed in Figure 9, there is a decrease in the rate of responding as the VI schedule increases. In this condition, Bird 3 was presented with the same VI schedules and in the same sequence as in Conditions 1 and 2 of this experiment.

Response rate on the VI20 s schedule during this condition was again equivalent with that obtained on this schedule in the other conditions of this experiment with Bird 3. The decrease in response rate as the VI schedule increased was positively decelerating, as the differences in response rate between schedules were smallest at the lower VI schedules, and increasingly large as the VI schedules increased.

The relation between response rate and the resulting obtained reinforcement is presented in Figure 10. Just as the response rate decreased on those schedules which produced the lower reinforcement densities, so did obtained reinforcers in this condition. At the lowest reinforcement density (i.e., on the VI80 s schedule), the total number of obtained reinforcers was approximately 55% of the total obtained at the highest reinforcement density (i.e., on the VI20 s schedule).

The decrease in obtained reinforcers is observable in both the VI and FR1 components of the sessions across schedules. This is unlike the results obtained in Condition 2 of this experiment with this subject, in which the number of obtained reinforcers remained fairly stable in the VI component of the sessions across schedules. In the present condition, this was due to the widely discrepant total number of obtained reinforcer between-schedules. It is conspicuous that the total number of reinforcers obtained decreased in those sessions in which the reinforcement density was lowest. In these sessions, as in all open-economy sessions throughout the experiment, once the VI component requirement was completed, no limit was imposed on the number of reinforcers that the subject could have obtained during the FR1 component. Thus, there was no apparent reason for the decrease in the total number of reinforcers obtained throughout the session when the reinforcement density decreased during the VI component of the session.

Even though the total number of reinforcers obtained decreased at low reinforcement densities, Bird 3's weight was not commensurately compromised. In fact, the subject's pre-session weight remained stable throughout the condition. As in Condition 2 of this experiment with Bird 3, the noticeable difference, as regards its weight, is between pre- and post-session weights. Here, again, at lower VI schedules there is a greater discrepancy between pre- and post-session weights than at higher VI schedules, where the discrepancy is negligible.

Bird 4

Condition 1: Closed-economy. When presented with this closed-economic condition, which required that all food consumed be obtained by responding according to various VI schedules of reinforcement, Bird 4's responding became inversely related to the overall rate of reinforcement. That is, response rate increased as the overall rate of reinforcement decreased. This relation is observable through the VI40 s, VI60 s, and VI80 s schedules. The schedules were introduced in the following sequence during this condition: VI20 s, VI60 s, VI40 s, VI80 s. Response rate on the VI20 s schedule, was slightly higher than that obtained on the VI40 s schedule. These data are presented in Figure 11.

The inverse relation between response rate and overall rate of reinforcement is reflected in the positively accelerating trend in response rate as the mean schedule interval increases.

The relation between response rate and obtained reinforcers is illustrated in Figure 12. Across the VI20 s and VI40 s schedules the

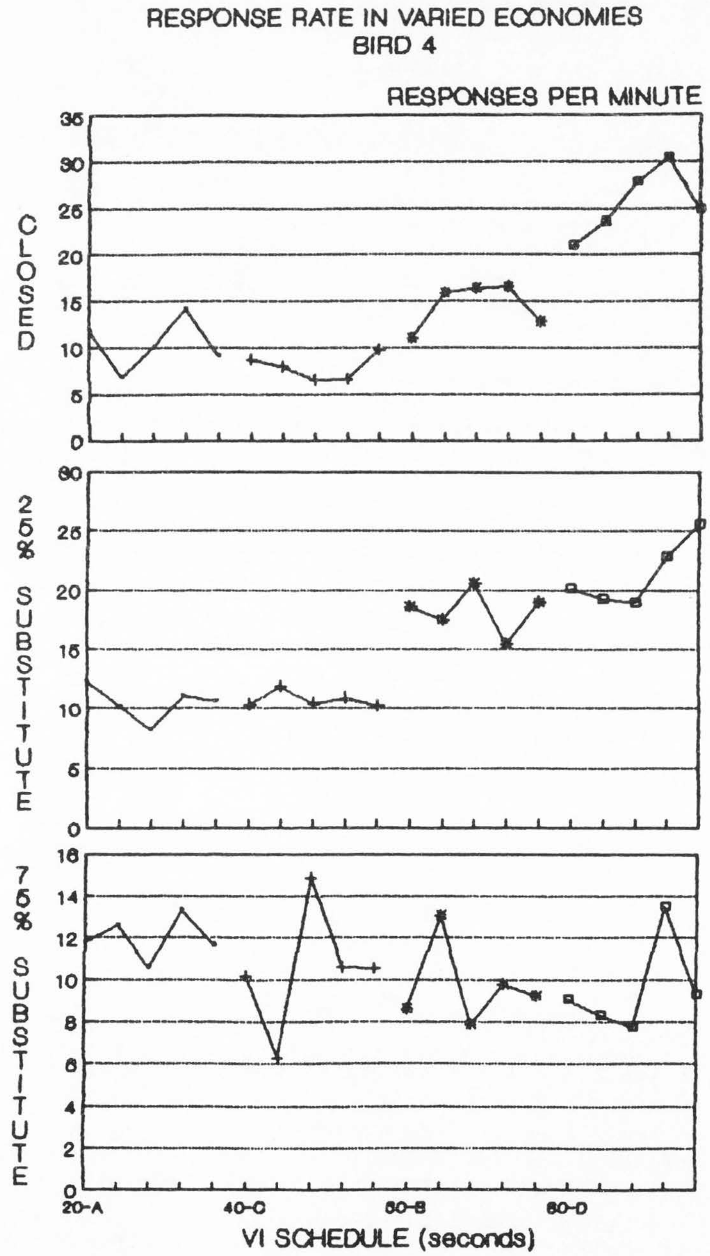


Figure 11. Response rate of Bird 4 in varied economies. The data from the last five sessions per schedule are shown. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

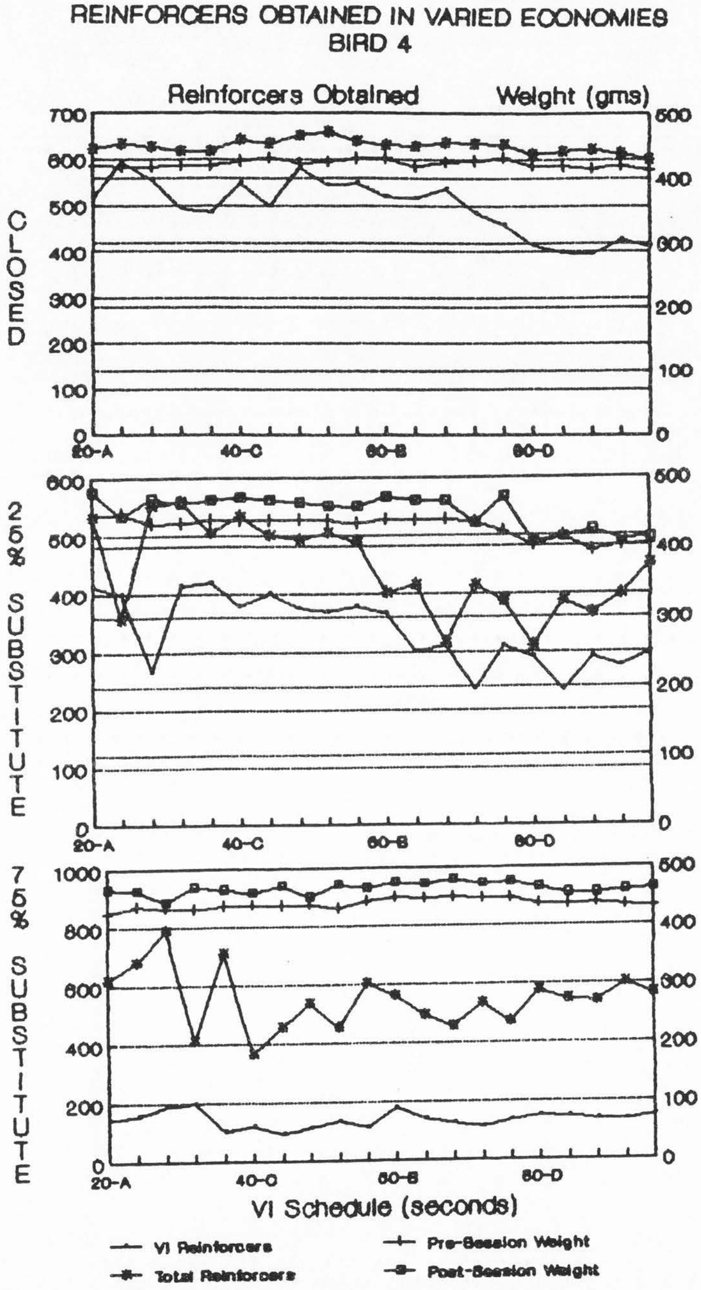


Figure 12. Reinforcers obtained by Bird 4 in varied economies. Data presented are from the last five sessions of each VI schedule presented. The total number of reinforcers obtained during the 11.5 hr session is presented together with the pre- and post-session weight (grams) of the subject. The introduction sequence of the schedules is denoted by the letter following the schedule (i.e., 20-"A").

obtained reinforcers are maintained, despite the increased challenge of the VI40 s schedule. On the VI60 s schedule, though, a decrease in obtained reinforcers is observed that continued to decrease on the VI80 s schedule. It is also notable that within-schedule obtained reinforcers varied more on the two lower schedules than on the higher two schedules.

Bird 4's weight remained stable throughout the condition. A marked pre- and post-session weight is observable at all schedule values, most notably on the VI40 s schedule. Thus, despite the increasing schedule challenge and consequent decrease in obtained reinforcement, this subject maintained its weight during the term and range of this condition.

Condition 2: Open-economy (75% substitute food). During this condition, the subject obtained 25% of its daily food by responding according to VI schedules of reinforcement. The subject obtained the balance of food from an alternate source, by responding according to an FR1 schedule. This condition represented the extreme open-economy of this experiment. Bird 4's response rate varied in a direct relation to the overall rate of reinforcement in this condition, as evidenced in Figure 11. As the overall rate of reinforcement decreased with increases in the VI schedule, response rate also decreased. This decrease is observable, even though within-schedule response rates vary from day to day.

The response rate of this subject on the two lowest schedules introduced (i.e., VI20 s and VI40 s), was roughly equivalent to those obtained on these schedules in Condition 1 of this experiment with this subject. Yet, at the higher VI values the response rates obtained in this condition are markedly lower than those obtained on the same schedules in Condition 1; thus the difference in the relation between response rate and overall rate of reinforcement becomes most clear as the reinforcement density is reduced (i.e., as the mean inter-reinforcement-interval increases). Related to this finding is the observation that the decrease in response rate between schedules in this condition is not as dramatic as the increase in response rate between schedules in Condition 1.

With a decrease in response rate as reinforcement density decreased, obtained reinforcement was more stable within schedules, as observed in Figure 12. On the VI20 s schedule of reinforcement there are notable between-session variations in the total number of obtained reinforcers (i.e., 50% decrease in obtained reinforcers from session 3 to session 4). These daily fluctuations decreased as the mean interval of the schedule increased, until at VI80 s between-session differences vary less than 5%. This decrease in the variability in total obtained reinforcers is, of course, accompanied by decreasing variability in the obtained reinforcers during the VI component of the sessions.

The across-schedule generally stable total obtained reinforcers is accompanied by stable weights, both pre- and post-session, across all phases of the condition. The weight maintained by Bird 4 during this condition was roughly 10% higher than that maintained during the closed-economy condition, Condition 1.

Condition 3: Open-economy (25% substitute food). In this open-economy condition, 75% of the subject's daily food was obtained during the VI component of the session, and the remaining food was obtained from the alternate source according to a FR1 schedule. In this way, this condition represented the intermediate economic condition between open and closed. The effects of this condition are presented in Figure 11.

In this condition, Bird 4's response rate was generally inversely related to overall rate of reinforcement. This relation is particularly apparent through the VI40 s, VI60 s, and VI80 s schedules. At the lowest VI schedule (i.e., VI20 2), the response rate is approximately equal to that obtained on the VI40 s schedule in this condition. Also, this response rate is comparable to those on this schedule in both Conditions 1 and 2 of this experiment.

Obtained reinforcers and weight of the subject in this condition are displayed in Figure 12. Notwithstanding the increase in response rate as reinforcement density decreased, total obtained reinforcers accompanied this decrease. The decline in obtained reinforcers is partially recuperated on the VI80 s schedule. There are greater daily differences in the total reinforcers obtained on the higher VI schedules, than on the lower.

This subject's weight remained stable across sessions. However, a slight decrease in weight occurred at the lower reinforcement densities. The weight loss is first observed on the VI60 s schedule. This lower weight is also evidenced on the VI80 s schedule. The decrease in weight coincided with a decrease in the difference between pre- and post- session weights, which had remained stable at higher reinforcement densities.

CHAPTER VI

DISCUSSION

The results of the present research are consistent with the reported distinction in the effects of open- and closed-economic conditions in traditional operant research. The results of Experiment I demonstrated that the feeding efficiency of the subjects was effected by schedule conditions. This necessitated the use of a new methodology that would accurately control the magnitude of reinforcement. Experiment II served as a replication and extension of Experiment I, and demonstrated that in a closed-economy, the relation between response rate and overall rate of reinforcement is direct, while the relation is inverse in an open-economy. Finally, a methodology for future examinations of economic conditions and the control they exert over behavior is suggested.

Experiment I

An examination of the data obtained from the three conditions presented during this experiment showed that the total number of responses made by the subjects across conditions varied in no clear or systematic way. Within conditions, there was also a general lack of systematic change in the data of individual subjects.

In the closed-economy condition, two of the four subjects showed no systematic changes from schedule to schedule. The other two subjects produced increasing total numbers of responses as the reinforcement density decreased. However, these increases in total number of responses were not accompanied by orderly changes in the number of reinforcers obtained.

Furthermore, all of the subjects obtained fewer reinforcers on the higher VI schedules than on the lower schedules, though the reduction in number of obtained reinforcers did not vary systematically with changes in reinforcement schedule. Despite the changes in number of reinforcers obtained from schedule to schedule, the subjects generally maintained stable weights throughout the condition. The small weight differences observed did not necessarily correspond to changes in obtained reinforcers. In fact, with all subjects there were several instances of decreases in obtained reinforcers accompanied by increases in weight within a single schedule. Instances in which obtained reinforcers increased and weight decreased within a schedule were also identified.

Similar results were obtained in the open-economy condition of the experiment, in which the subjects obtained a percentage of their total daily reinforcers by responding according to VI schedules of reinforcement, and the remainder from a substitute source by responding according to an FR1 schedule. Monitoring the consumption of food showed little relation between decreased reinforcement density, obtained reinforcers, and food consumption. That is, despite obtained-reinforcer decreases, as reinforcement density decreased, overall consumption of food remained the same in this condition.

The results of this experiment suggest, among other things, that as reinforcement density decreased the subjects increased the amount of food consumed at each hopper lift. Thus, at low VI schedules, which produced high reinforcement densities (i.e., on VI10 s, an average of six reinforcements per min can be obtained), the subjects ate fewer pieces of chow each time a response produced reinforcement. Conversely, at low reinforcement densities, such as those produced by higher VI schedules (i.e., on VI80 s, reinforcement is available on the average only once every 1.33 min), the subject increased its feeding efficiency, consuming more pieces of chow per reinforcement. By improving efficiency, the subjects conserved the overall amount of food consumed regardless of the specific reinforcement density, and consequently were able to regulate their weights. Unfortunately, the efficiency of eating does not appear to have varied consistently in this simple way. Rather, as the length of the hopper lift was held constant throughout the experiment, magnitude of reinforcement could have varied as a function of reinforcement density imposed by the schedule in effect, together with the subject's rate of responding, individual differences between subjects (i.e., speed of travel to the hopper and speed of consumption), or level of deprivation as a function of session time. Furthermore, these variables may have interacted. As they were not controlled, there is no way to judge at this time which combination of variables may have been responsible for the results.

Anecdotal information obtained by actually observing subjects in the chamber corroborates the possibility that reinforcement magnitude was not controlled during the experiment. It was observed that at lower VI schedules, head transit time to the hopper from the response key was slower, the subjects ate more slowly, and on several occasions, subjects were observed to discard pieces of chow by dropping them through the grid floor of the chamber and then return to the hopper to resume eating. That is to say, they did not eat all they could have. At higher schedules, however, the subjects appeared to move more quickly to the hopper, eat more rapidly and were never observed to discard food.

Although no similar research has been conducted in which magnitude of reinforcement has been controlled, several experiments have demonstrated that response rates on FI schedules of reinforcement vary directly with magnitude of reinforcement (Guttman, 1953; Hutt, 1954; Stebbins, Mead, & Martin, 1959). Rate of responding on FR1 has also been shown to vary directly with magnitude of reinforcement (Guttman, 1953). Epstein (1985) demonstrated that, although the amount of grain pigeons consume is assumed to be some orderly function of the duration of the hopper cycle, the actual amount of grain consumed is a function of both the magazine cycle and the type of hopper employed. Epstein showed that Lehigh Valley Electronics feeders, the type of feeder employed in the present experiment, provided continuous access to grain throughout the hopper cycle. Thus, during the 4.4 s cycles employed here, it is likely that there was no constraint on feeding imposed by the design of the feeders.

Combined, these results confound the utilization of the data in an examinationo of the relation between responding and economic condition. The differences in responding that may be produced by the differences in economic condition requires that magnitude of reinforcement be rigorously controlled. In fact, it may be that lack of control over magnitude of reinforcement in other research, due to the same or similar circumstances, has effected results without being detected.

Experiment II

In this experiment, magnitude of reinforcement was stringently controlled by using pellet feeders that delivered a single 45 mg pellet when reinforcement was signalled. This modification allowed precise control over the amount of reinforcers obtained during each delivery, and negated magnitude of reinforcement as an independent variable for the purposes of the experiment. Thus, the results obtained can be confidently attributed to manipulations of the schedules of reinforcement and economic conditions presented.

The principal objectives of the experiment were to determine whether in a closed-economy the relation between responding and the overall rate of reinforcement was inverse, while the relation in an open-economy was direct. Additionally, the possibility that open- and closed-economies represented two parametric extremes along a continuum was examined. It has previously been reported that responding in a closed-economy is disparate from that in an open-economy (Hursh 1978, 1980, 1984, 1986). Hursh has reported that in closed-economies, the rate of responding increases as the overall rate of reinforcement decreases. This is in direct disagreement with commonly held tenets regarding responding in open-economies, which hold that the rate of responding decreases as overall rate of reinforcement decreases (see Catania, 1963, and Catania & Reynolds, 1968). Thus the question of whether the economic condition effects responding will continue in the literature until the reported differences in responding can be accounted for.

It is commonly held that the effects of different types of schedules of reinforcement are systematic and orderly in individual organisms, and that these effects are replicable within and across species (Zeiler, 1977). Sidman (1960) has suggested that one way to evaluate the adequacy of experimental control is to see if the behavior typical of specific schedules is reproduced. Such judgments and commonly held tenets may be restricted to responding in specific economic conditions. If economic condition exerts control over responding, it will be necessary to broaden understanding of this control and the way it is manifested in responding.

The current experiment sought to provide information that would assist in clarifying the role, if any, of economic condition on responding. This was accomplished by manipulating density of reinforcement through the use of various VI schedules of reinforcement, and through the manipulation of economic conditions.

Figure 13 is a representation of the relation between response rate and reinforcement density on VI schedules of reinforcement. The data points, although approximate, are based on results of experiments reported in the literature on responding under VI schedules of reinforcement (e.g., Catania, 1963; Catania & Reynolds, 1968; Hursh, 1978, 1980). This depiction shows that as reinforcement density decreases from an average of 3 per min to 1 per min, response rate increases dramatically in a closed-economy. Given the same decrease in overall rate of reinforcement, in an open-economy it produces quite different results. High reinforcement density produces high response rates, while low reinforcement density produces low responses rates; a direct relation.

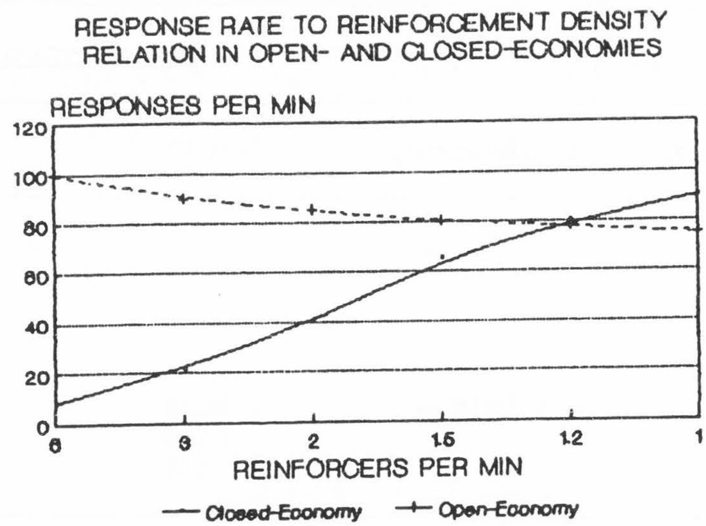


Figure 13. Representation of the relation between response rate, in responses per min, and reinforcement density, in reinforcements per min, in a closed- and an open-economy. Data points for the closed-economy were derived from Hursh (1978, 1980). Open-economy data points were derived from Catania and Reynolds (1968).

Table 5 shows that the results of the present experiment are generally consistent with these previous findings. In the case of the closed-economy, in which the subjects obtained 100% of their total daily food by responding according to the VI schedules presented, an inverse relation was obtained between response rate and overall rate of reinforcement with three of the four subjects. Only the results obtained with Bird 3 were inconsistent with those of the other subjects.

Table 5

Results of Experiment II as regards the Relation Between Response Rate and Reinforcement Density in Different Economic Conditions

Economic Condition	Closed	Intermediate	Open
Relation between Response Rate and Reinforcement Density:			
Inverse	Bird 1 Bird 2 Bird 4	Bird 4	
Direct		Bird 2 Bird 3	Bird 1 Bird 2 Bird 3 Bird 4
Equivocal	Bird 3	Bird 1	

As regards the relation between rate of responding and overall rate of reinforcement in an open-economy, in which the subjects obtained

25% of their total daily reinforcers by responding according to VI schedules and the remainder from an alternate source of food, a direct relation was obtained with all four subjects. Thus, as reinforcement decreased as a function of increases in the mean interval between reinforcements, the rate of responding of all subjects decreased.

When presented with an intermediate open-economy, one in which the subjects were required to obtain 75% of their total daily reinforcers by responding according to presented VI schedules, the results were inconsistent. The results obtained with Bird 4 were consistent with an inverse relation between response rate and overall rate of reinforcement, while those obtained with Birds 2 and 3 were consistent with a direct relation between these two variables. Finally, the results obtained with Bird 1 were inconsistent with either a direct or an inverse relation between overall rate of reinforcement and response rate in this intermediate open-economy. Such findings are what might be expected if this condition is a transition position between two extreme points on a continuum.

Conclusions

Open- and Closed-Economies

The results of the present research program generally confirm that economic condition does have a controlling effect on responding in operant research. When exposed to a closed-economy in which there is no source of substitute food, the subjects generally increase their rate of responding in the face of the increasing challenge of decreasing reinforcement density. When an alternate source of food is available, as in the case of the extreme open-economy condition of this experiment, response rate consistently decreased as reinforcement density decreased. However, the exact nature of the control exerted by the economic condition remains somewhat unclear. Individual differences among the subjects were noted regarding the effects of the closed-economy and the intermediate open-economy on responding. Furthermore, the lowest VI schedules employed generated lower response rates than those generated by the higher VI schedules, regardless of economic condition.

In order to clarify these results, it will be necessary to discuss them within existing conceptual frameworks on responding in open- and closed-economies. However, before this, it is important to try to account for inconsistencies that have been obtained in the current data. To accomplish both of these objectives, the current results must be viewed in light of those obtained in other related experiments. Unfortunately, due to the fact that there has been little operant research conducted in closed-economic conditions, and that there are methodological differences between the open-economy conditions of the present experiment and other open-economy operant investigations, it is difficult to draw direct comparisons. In typical operant research, subjects are food-deprived to 80% of their free-feeding weights, sessions are relatively short, and make-up, or substitute food, is provided in the home cage at minimal cost. These are all significant departures from the current research methodology.

Responding on VI Schedules

The results obtained from the lowest VI schedules of reinforcement presented to each subject in the present research (i.e., VI10 s and VI20 s) show consistent rates of responding within subjects, across economic conditions. Consequently, the rates of responding obtained on these schedules frequently conflicted with those obtained on the other schedules presented, regardless of the economic condition in effect.

This seeming lack of sensitivity of responding on these VI schedules to economic condition may be accounted for by the following. First, it is important to note that, in general, the subjects in this research responded at rates that are lower, across schedules and conditions, than those reported in other VI schedule research. In their open-economy VI experiments with pigeons, Catania (1963), and Catania and Reynolds (1968), reported response rates of approximately 67 responses per min on a VI20 s schedule, decreasing to approximately 58 responses per min on a VI60 s schedule. In the present research, response rates varied from a low of 9 responses per min (Bird 4 on a VI80 s in an open-economy with 75% substitute food) to a high of 65 responses per min (Bird 2 on a VI70 s in a closed-economy). Lower response rates than those reported in other open-economy experiments were common in the present research. Higher rates, comparable to those reported by Catania (1963), and Catania and Reynolds (1968), were the exception.

It is likely that the higher rates reported in the open-economy literature are due to the fact that the subjects were being maintained at weights that are significantly below their free-feeding weights. This conclusion is supported by the results of Zeigler et al. (1971), in which they demonstrate that the frequency of feeding responses increases as a function of loss of body weight. Furthermore, in two closed-economy studies conducted by Hursh (1978, 1980), response rates were comparable to those obtained here. That is, on a VI20 s schedule, Hursh's subjects' response rate was 8.33 responses per min and, while on a VI60 s schedule an average of approximately 75 responses per min were made. Of course, it is important to point out that Hursh's subjects were monkeys. There are likely species differences that interact which affect this comparison. The evidence suggests that by not artificially reducing the subjects' weight, the research methodology produced lower response rates.

When the between-subject and between-condition response rates obtained on low VI schedules are considered, in light of the generally low response rates obtained throughout the experiment, it is conceivable the subjects may not have been responding in accordance with an interval schedule. Rather, the low rate-short interval interaction seems to have effectively produced responding according to a low fixed-ratio schedule of reinforcement. Such responding is characterized by a pause after reinforcement and a uniform response rate from onset of responding to subsequent reinforcement (Ferster & Skinner, 1957).

This effect explains the consistency of the response rates within subjects across conditions. Regardless of the economic condition to which the subject was exposed, the same response distribution on these low VI schedules produced the same distribution of reinforcement. Therefore, responding would be (and was) insensitive to economic condition. It appears that the use of low VI schedules of reinforcement is contraindicated in a test of the control exerted by economic condition over responding when the subject's weight is not reduced.

<u>Responding, Obtained Reinforcement and Weight in Closed-Economies</u>

The results obtained from Bird 3 in Condition 1: Closed-economy, were anomalous when compared with that obtained with the three other subjects. With these other subjects, results were obtained that were consistent with an inverse relation between response rate and reinforcement density. However, with Bird 3, no differences were obtained in rate of responding as reinforcement density was changed. This appears to be related to the interaction of responding and weight of the subjects.

It is apparent, in the results from all of the subjects, to varying degrees, that as reinforcement density decreased, their pre- and post-session weight differences also decreased. Thus, it appears that at higher reinforcement densities, the subjects tended to consume a greater number of reinforcers than were necessary to maintain a stable, free-feeding weight. Zeigler (1976) has reported that adult pigeons given unrestricted access to food and water characteristically maintain relatively stable body weights (+/- 10%) in the face of significant variations in their daily food intake. This is the case with the subjects in the present study, particularly during the open-economy conditions, and at the higher reinforcement densities to which they were exposed in the closed-economy condition.

When the subjects were exposed to the increased challenge of lower reinforcement densities in the closed-economy, responding increased, but consumption declined. The decline in obtained reinforcers first resulted in smaller pre- to post-session weight differences, while pre-session weights themselves remained stable. This is also observable in the data of all four subjects. However, the decreases in obtained reinforcers on the higher VI schedules also effected the pre-session weights of the subjects, which declined for Birds 1, 2 and 4. These subjects increased their response rates in the presence of the decline in obtained reinforcement and weight.

Bird 3, on the other hand, maintained a stable weight throughout the condition, despite decreases in obtained reinforcers. While the excesses in consumption that were apparent at higher reinforcement densities disappeared at the lower reinforcement densities, the actual pre-session weight of this subject was maintained at all reinforcement densities in this closed-economy. It appears this subject compensated for decreases in obtained reinforcers in ways other than increasing response rate, as did the other subjects. It is conceivable this subject decreased its activity level in and out of the chamber and otherwise conserved its weight. Had the subject been further challenged, such that obtained reinforcers continued to decline, or had been maintained at a low level over a longer period, it is possible that weight and response rate would have eventually been effected.

The role of water consumption on both pre- and post-session weights should not be overlooked. It is conceivable, though unlikely, that the weights of the subjects in the present research were effected by increased water consumption when food availability was decreased.

This is improbable because water consumption of pigeons decreases as food consumption decreases. It cannot be ruled out, however, because water consumption was not carefully measured during the research.

This interaction of response rate, obtained reinforcers, and weight might also account for the dramatic increases in response rates in the closed-economy condition when compared with the relatively small decreases in response rate when reinforcement density decreases in open-economy conditions. In the closed-economy, total-obtained reinforcers and weight appear to be a function of response rate and calorie conservation, whereas in open-economies, total-obtained reinforcers and weight are a combined function of response-dependent and response-independent obtained reinforcers, calorie conservation, and manipulation of the experimenter. Response rate is linked only to obtained reinforcers during the experimental session in typical operant experiments and the VI component of the sessions of the present research.

It appears that, in research on the effects of economic conditions on responding, it is important to monitor the interactions between responding, obtained reinforcers, and weight. This is an area that requires additional experimental inquiry.

Closed- and Open-Economies: A Continuum Between Parametric Extremes?

It had been proposed that open- and closed-economies represent a continuum between two parametric extremes, rather than two opposing alternatives. It was argued that if this was the case, then by increasing the amount of daily food provided as a substitute commodity, the response-to-reinforcement relation would gradually shift from a closed-economy type (inverse) to an open-economy type (direct). To test this possibility, an intermediate open-economy was introduced, in which the subjects obtained 75% of daily consumption by responding during the VI component of the session, after which food was available throughout the remainder of the session from an alternate source.

The results provide evidence that such a shift in the relation between response rate and overall rate of reinforcement occurred with two of the subjects, Birds 2 and 3. However, the opposite relation was obtained with Bird 4. The results obtained with Bird 1 during the intermediate open-economy, were compromised by cycling, and will therefore be treated later. Further, the results previously discussed regarding Bird 3 in the closed-economy, makes the analysis difficult with this subject, because an inverse relation between responding and reinforcement was not clearly obtained.

The continuum effect, or transition area, is most clear in the results obtained with Bird 2. That is, in the intermediate open-economy condition, there is a direct relation between response rate and overall rate of reinforcement that has been identified as typical of responding in an open-economy. Additionally, the direct relation appears to be modulated by the degree of the open-ness of the economy. That is, the decreases in responding that accompany decreases in reinforcement density are smaller in the intermediate open-economy condition than they are in the open-economy condition with this subject. Hence, it appears that as the economic condition more closely approximates a closed-economy (i.e., less food is available as a substitute), responding is more like that obtained in the closed-economy, yet it retains characteristics of that obtained in an open-economy. Most likely this can be attributed to the requirement that the majority of total daily reinforcers be obtained during the work session. This intermediate open-economy closely approximates the open-economies employed in typical operant experiments, as is the less dramatic decrease in response rate when challenged by decreased reinforcement densities.

This direct relation between response rate and overall rate of reinforcement is also observed in the results obtained with Bird 3, in both open-economy conditions. Drawing conclusions from the results obtained with Bird 3 regarding a continuum between open- and closed-economies is mitigated by the subject's responding in the closed-economy, which was previously discussed.

Bird 4 produced results inconsistent with those obtained with Birds 2 and 3. This subject's rate of responding was in inverse relation to reinforcement density in the intermediate open-economy, which has been identified as being characteristic of the relation obtained in a closed-economy. The increase in response rate as reinforcement density decreased is not as dramatic in the intermediate open-economy as in the closed-economy, but is apparent nonetheless.

Although the results of the present research are somewhat inconclusive on this issue, they do suggest that open- and closed-economies lie along a continuum. It appears that the specific manifestations of this continuum at intermediate stages may vary from subject to subject, and that response rate does not vary in a singularly simple relation to the amount of substitute food provided. Further research on this issue is warranted to determine the variables and their interaction that account for the shift in relation, from direct in an open-economy, to inverse in a closed-economy, between response rate and overall rate of reinforcement. The percentage of reinforcers delivered in the open-economy conditions of the research, 25 and 75, are discrete. In future research, intermediate percentages will have to be employed to further clarify the continuum issue.

The Integration of Delayed Contingencies into Current Responding

The results of this research are in support of a distinction in the relation between responding and overall rate of responding that is dependent on economic condition. It is argued that in a closed-economy, the organism must obtain its total allotment of a commodity, such as food in the present case, by responding according to scheduled contingencies. Either the requirements of the contingencies of reinforcement are satisfied, or the commodity is not delivered. There are no alternative sources of the commodity available. In such an arrangement, the relation of responding to overall rate of reinforcement is maintained to be inverse: As overall rate of reinforcement decreases, response rate increases. By responding in an inverse relation to reinforcement density, the organism can maintain a sufficient number of reinforcers, within limits. These limits are determined by the reinforcement density itself and the organism's ability to respond to it. If the density of reinforcement is limited beyond the subject's ability to respond to it, reinforcement and responding will cease. At densities below this point, the subject will continue to increase its responding in response to the challenge of decreasing density.

In the case of the open-economy, there are alternative sources of the commodity. The commodity may be supplied from the different sources according to the same, or similar contingencies. A familiar case is the concurrent schedule methodology frequently employed to study choice behavior (Herrnstein, 1961). Here, the same commodity, typically food, water, or electrical brain stimulation, is concurrently available from two or more sources for responding, according to different schedules of reinforcement.

In an open-economy arrangement, responding is effected by the availability of a commodity from various sources. In concurrent schedule research, for example, it has been repeatedly found that responding for reinforcement from any one of the various available sources of reinforcement roughly matches the availability of reinforcement from that source (Herrnstein, 1961; de Villiers, 1977).

Hursh (1980, 1984, 1986) argues that the typical operant experimental arrangement represents an open-economy. In this arrangement, there are at least two alternative sources of food: the experimental chamber, according to various experimenter controlled schedules, and the home-cage, on a response-independent basis. Hursh contends that responding maintained by food reinforcers in the experimental chamber is effected by the food that is provided, albeit often delayed by 15 min or more, in the home-cage on a response independent basis.

Unquestionably, in order for Hursh's contention to be upheld, it is imperative that experimental subjects are able to integrate delayed contingencies into their current responding. Timberlake and Peden (1987) point out that the distinction between open- and closed-economies based on commodity-substitution effects in the open-economy, assumes the subject in the open-economy anticipates access to the substitute low-cost food that will be provided in the home-cage. In this way, the basic mechanisms underlying responding are judged to be different in the two types of economies.

In the open-economy, responding is assumed to be based on incentive effects. Because there is no relation between responding in the session and total food obtained, the more frequent and larger each reinforcer, the greater the responding, and subsequently the greater the number of reinforcers obtained. As magnitude and/or frequency of reinforcement declines, however, the subject increasingly postpones its intake, thereby reducing its responding, until the session ends and the less costly, substitute food becomes available. Demand for food is thus elastic during the experimental session.

In the closed-economy, responding is assumed to be based on regulatory effects. Because total daily consumption is a direct result of responding during the experimental session, the more frequent and/or larger the reinforcers, the less responding is required for survival. Conversely, as reinforcers become smaller and/or less frequently, the greater will be responding.

Timberlake and Peden (1987) disagree that the mechanisms underlying responding would be different in situations that vary only by economic condition, and maintain that organisms are unable to integrate contingencies that are delayed by more than a few minutes. Timberlake, Gawley and Lucas (1987) demonstrated with rats that food available more than 16 min in the future (after termination of the session) did not suppress current (within session) responding. They, therefore, ruled out substitution effects from postsession feeding, suggesting that such food would have to be provided immediately after the session, and suggested that the differences obtained in open- and closed-economy experiments were more likely due to variables other than substitution, such as reward magnitude and density, and motivation level.

The present research controlled for reward magnitude through the use of constant 45 mg food pellets as reinforcers throughout. Reward density was controlled by the schedules of reinforcement employed. Finally, by not artificially manipulating the subjects' weight, motivation was controlled. That is, all variations in weight (motivation) during the study were due to subject-schedule interactions. To account for day-to-day fluctuations in weight, and, consequently, motivation which occur with pigeons (Zeigler, 1976), percentages of food to be obtained during the VI components of the open-economy sessions were based on the previous day's total reinforcers obtained.

Given these controls, it appears that the direct relation between responding and overall rate of reinforcers obtained in the present research in the open-economy conditions, can be attributed to the presentation of delayed, low-cost substitute food. This is clear, based on the 8 min COD that was imposed between the termination of the

VI component and the onset of the FR1, or substitute food, component. This delay is apparently brief, falling within the relatively small time window that Timberlake and Peden (1987) suggest can be integrated into responding by rats. Other evidence from the present research suggests, however, that the subjects incorporated contingencies delayed by many hours.

Responding during the FR1 component of the open-economy conditions of Experiment II was not constrained in any way other than by the total length of the session. From the onset of the component, reinforcement was available until the total session length of 11.5 hours had passed, at which time the session terminated and the subject was returned to the home-cage, where no substitute food was provided. The results obtained in the open-economy conditions indicate that responding during the FR1 component of the sessions, and consequently the amount of substitute food consumed, was effected by the consequences this responding would have on the VI component of the following session, in a type of feed-forward mechanism. This effect is most apparent when the results obtained with Bird 1 in the intermediate open-economy condition are compared with those obtained with this subject in the other conditions of the experiment.

In the results of Condition 1, the closed-economy condition, it was apparent that as reinforcement density decreased, responding increased at all but the highest VI schedule (i.e., VI70 s), which was previously accounted for. Also, at the low reinforcement densities, the subject's weight decreased. In Condition 2, the extreme open-economy condition of the experiment in which 75% of total daily reinforcement was provided as substitute food, low reinforcement density was accompanied by low rates of responding. High reinforcement densities were accompanied by high response rates, with the exception of the VI10 s schedule which has been discussed.

It is in Condition 2, the extreme open-economy, that the integration of delayed contingencies is particularly noted. As in Condition 1, when reinforcement density decreased, the subject's weight is compromised. This is noted in both the pre-session weights and the difference between the pre- and post-session weights. In Condition 1, this decrease is due to the unavailability of substitute food. However, in Condition 2, substitute food is available without restriction of the total consumed, during the FR1 component of the sessions. Despite this availability, total-obtained reinforcers decreased as reinforcement density decreased during the VI component of the sessions. That is, consumption during the FR1 component of the sessions is decreased in those sessions where reinforcement density is lowest during the VI component of the sessions, even at the expense of weight. This effect is explained by the results of Condition 3, the intermediate open-economy.

It will be recalled that during Condition 3, the obtained reinforcers during the VI component of the sessions was held constant at each schedule, rather than manipulated based on the total-obtained reinforcers during the previous session. This successfully terminated the subject's consummatory day-to-day cycling. Thus, in this condition, with this subject, when total daily-obtained reinforcers had no effect on the number of reinforcers that had to be obtained during the following VI session, the subject maintained a reasonably stable intake of food across schedules, such that weight remained stable throughout the condition. This was so even at the lowest reinforcement densities during the VI component of the sessions. In fact, the subject's stable weight during this condition was the heaviest constant weight of the subject during the experiment.

These results suggest that when the number of reinforcers to be obtained during the VI component of a session is dependent on the number of reinforcers obtained during the previous session, and this then is combined with low reinforcement densities during the VI components of the session, the subject limited total daily intake. In this way, the number of reinforcements required to complete the VI component of the sessions was kept low. This supports the argument that Bird 1 integrated contingencies from one session to the next on the order of 24 hrs.

A similar effect is observed in the results obtained with the remaining subjects. For example, it has been conspicously noted that the total number of reinforcers obtained by Bird 3 in the intermediate open-economy condition of Experiment II decreased in those sessions where the reinforcement density was lowest, despite the continued availability of food during the FR1 component of the sessions. Of course, in the case of Birds 2, 3 and 4, obtained reinforcers during the VI component were contingent on the previous day's total-obtained reinforcers, across all open-economy conditions. In Condition 3, the intermediate open-economy, when high total-obtained reinforcements had a dramatic effect on the total number of reinforcements necessary to terminate the VI component of the subsequent session, total-obtained-reinforcements declined considerably as reinforcement density decreased. This occurred despite time being available to obtain a higher total number of reinforcements. Further, as this decrease occurred, pre- and post-session weight difference generally decreased.

In additional support of the extreme open-economy, Condition 2, when total-obtained reinforcers had only a small effect on the following session's VI component requirement, the total reinforcers obtained increased considerably as reinforcement density in the VI component of the sessions decreased.

Thus, support is provided to conclude that these subjects, given the present methodology, integrated contingencies across long time periods, longer than has previously been reported (cf. Timberlake and Peden, 1987).

Conclusions and Recommendations for Future Research

The results of the present research program contribute to the growing evidence that economic conditions do have a controlling effect on the relation between responding and overall rate of reinforcement. It appears that this effect in either economy type is due to the integration of delayed contingencies into present responding, and that the subjects of this research integrated contingencies over longer periods than has previously been reported. Furthermore, the results of this research suggest that rather than the performance in a closed-economy being the result of regulatory effects, while that in an open-economy is the result of incentive effects, both regulatory and incentive effects are present in both economic conditions. The exact control of these effects and their interactions are not clear, however, and should be further examined.

From the results of this research, it also appears that, rather than representing two parametric extremes, open- and closed-economies represent positions along a continuum. Yet the precise way in which the variables produce the continuum have not been identified. Although the amount of substitute food provided appears to play an important role, the results of this research indicate there are other variables that likely interact with the amount of substitute food. These additional factors must be identified through further investigation.

The results of this research indicate that response rates are, in general, lower when subjects are not food deprived to some arbitrary weight. When these lower response rates are maintained by VI schedules with relatively short mean inter-reinforcement-intervals (IRIs), (i.e., 10 s or 20 s), the subjects tend to respond as though on low fixed-ratio schedules. Therefore, research into closed- and open-economy responding should employ interval schedules with greater IRIs. The results of the closed-economy condition in the present research suggest the subjects were not sufficiently challenged to test the limitations of the inverse relation between response rate and overall rate of reinforcement. If VI schedules greater than VI70 s and VI80 s had been employed, this relation may have disintegrated. Further experimentation will assist in determining the constraints, if any, on the inverse relation between responding and reinforcement in closed-economies.

It is also clear that greater care need be taken with laboratory methods to ensure that results obtained can be unquestionably attributed to experimenter manipulations. Common wisdom regarding instrumentation and methods must be periodically reviewed in light of the technological advances being made that permit better control of the experimental environment. Such review will strengthen both experimental practices, and skill in predicting and controlling the behavior of organisms. As Broca (cited in Strauss, 1968) said, "The least questioned assumptions are often the most questionable" (p. 232).

Above all, the present research indicates that it is now necessary to reconsider the issue of delayed contingencies and to conduct the experimental analyses that will allow researchers to better incorporate their effects into the science of behavior. Careful consideration of current micro-economic theory may provide valuable information to guide the development of the related research program.

REFERENCES

Alvord, R. (1978). Home token economy. Champaign, IL: Research Press.

Battalio, R. C., Kagel, J. H., Winkler, R. C., & Winett, R. A. (1979). Residential electricity demand: An experimental study. The Review of Economic and Statistics, 61(2), 180-189.

Bio-Serve (1988). Bio-Serve sales catalog, The Bio-Serve Company. Frenchtown, NJ: Author.

Boulos, Z., & Terman, M. (1980). Food availability and daily biological rhythms. Neuroscience and Biobehavioral Reviews, 4, 119-131.

Brady, J. (1982). Conceptual and methodological approaches to long-term research requirements. In J.V. Brady (Ed.), Human behavior in space environments: A research agenda (pp. 21-32). Baltimore, MD: Johns Hopkin University School of Medicine.

Catania, A. C. (1963). Concurrent performances: Reinforcement interactions and response independence. Journal of the Experimental Analysis of Behavior, 6, 253-263.

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.

Clark, F. C. (1958). The effect of deprivation and frequency of reinforcement on variable-interval responding. Journal of the Experimental Analysis of Behavior, 1, 221-228.

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

Collier, G. H. (1983). Life in a closed economy: The ecology of learning and motivation. In M. D. Zeiler & P. Harzem (Eds.), Advances in analysis of behavior, Vol. 3. (pp. 223-276). Chichester: Wiley.

Collier, G. H., Hirsch, E., & Kanarek, R. (1977). The operant revisited. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 116-140). Englewood Cliffs: Prentice-Hall, Inc.

Delius, J. (1983). Learning. In M. Abs (Ed.), Physiology and behavior of the pigeon (pp. 327-355). NY: Academic Press.

de Villiers, P. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 313-339). Englewood Cliffs, NJ: Prentice-Hall.

Elsmore, T. F., Fletcher, G. V., Conrad, D. G., & Sodetz, F. J. (1980). Reduction of heroin intake in baboons by an economic constraint. Pharmacology, Biochemistry and Behavior, 13, 729-731.

Epstein, R. (1985). Amount consumed varies as a function of feeder design. Journal of the Experimental Analysis of Behavior, 43, 63-72.

Fantino, E. (1977). Conditioned reinforcement: Choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 313-339). Englewood Cliffs, NJ: Prentice-Hall.

Farmer, J. (1963). Properties of behavior under random interval reinforcement schedules. Journal of the Experimental Analysis of Behavior, 6, 607-616.

Felton, M., & Lyon, D. O., (1966). The post-reinforcement pause. Journal of the Experimental Analysis of Behavior, 6, 131-134.

Ferster, C. B., & Skinner, B. F. (1957). Schedules of reinforcement. NY: Appleton-Century-Crofts.

Findley, J. D. (1959). Behavior output under chained fixed-ratio requirements in a 24-hour experimental space. Journal of the Experimental Analysis of Behavior, 2, 258.

Fischer, E. B., Winkler, R. C., Krasner, L., Kagel, J. H., Battalio, R. C., & Bassmann, R. L. (1978a). Economic perspectives in behavior therapy: Complex interdependencies in token economies. Behavior Therapy, 9(3), 1-403.

Fischer, E. B., Winkler, R. C., Krasner, L., Kagel, J. H., Battalio, R. C., & Bassmann, R. L. (1978b). Implications for concepts of psychopathology of studies of economic principles in behavior therapy programs. The Journal of Nervous and Mental Disease, 166, 187-194.

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

Green, L., & Kagel, J. H. (Eds.). (1987). Advances in behavioral economics: Vol. 1. Norwood, NJ: Ablex Publishing Corporation.

Grice, G. R. (1948). The relation of secondary reinforcement to delayed reward in visual discrimination learning. Journal of Experimental Psychology, 38, 1-16.

Guttman, N. (1953). Operant conditioning, extinction and periodic reinforcement in relation to concentration of sucrose used as reinforcing agent. Journal of Experimental Psychology, 46, 213-244.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 4, 267-272.

Hoag, A. J., & Hoag, J. H. (1986). Introductory economics. Englewood Cliffs, NJ: Prentice-Hall.

Hodos, W., & Trumbule, G. H. (1967). Strategies of schedule preference in chimpanzees. Journal of the Experimental Analysis of Behavior, 6, 503-514.

Honig, W. K., & Staddon, J. E. R. (1977). Introduction. In W. K. Honig and J. E. R. Staddon (Eds), Handbook of operant behavior. Englewood Cliffs,NJ: Prentice-Hall.

Honig, W. K. (1965). Discrimination, generalization, and transfer on the basis of stimulus difference. In D. Mostofsky (Ed.), Stimulus generalization (pp. 218-254). Stanford, CA: Stanford University Press.

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). Economics 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.

Hursh, S. R. (Month unknown, 1986). Factors defining open and closed economies: Mapping the continuum. (Available from Harvard University, Cambridge, Mass).

Hutt, P. J. (1954). Rate of bar pressing as a function of quality and quantity of food reward. Journal of Comparative Physiological Psychology, 47, 235-239.

Imam, A. A., & Lattal, K. A. (1988, May). Alternative reinforcement in economic context. Paper presented at the meeting of the Association for Behavior Analysis, Philadelphia, PA.

Kagel, J. H., & Winkler, R. C. (1972). Behavioral economics: Areas of cooperative research between economics and applied behavior analysis. Journal of Applied Behavior Analysis, 5, 335-342.

Kaplan, M. (1952). The effects of noxious stimulus intensity and duration during intermittent reinforcement of escape behavior. Journal of Comparative and Physiological Psychology, 45, 538-549.

Kayser, C. (1965). Hibernation. In W. V. Mayer & R. G. Van Gelder (Eds.), Physiological mammalogy: Vol. 2. Mammalian reaction to stressful environments (pp. 179-276). NY: Academic Press.

Kazdin, A. E. (1977). The token economy. NY: Plenum Press.

Lattal, K. A., & Harzem, P. (1984). Present trends and future directions. Journal of the Experimental Analysis of Behavior, 42, 349-351.

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

Logan, F. (1964). The free behavior situation. In D. Levine (Ed.), Nebraska Symposium on Motivation Vol. 12. (pp. 99-128). Lincoln: University of Nebraska Press.

Lucas, G. A. (1981). Some effects of reinforcer availability on the pigeon's responding in 24-hour sessions. Animal Learning & Behavior, 9, 411-424.

McSweeney, F. K. (1982). Positive and negative contrast as a function of component duration for key pecking and treadle pressing. Journal of the Experimental Analysis of Behavior, 37, 281-293.

Mellitz, M., Hineline, P. N., Whitehouse, W. G., & Laurence, M. T. (1983). Duration-reduction of avoidance sessions as negative reinforcement. Journal of the Experimental Analysis of Behavior, 40, 57-67.

Norborg, J., Osborne, S., & Fantino, E. (1983). Duration of components and response rates on multiple fixed-ratio schedules. Animal Learning & Behavior, 11, 51-59.

Rachlin, H. (1982). Absolute and relative consumption space. In D. J. Bernstein (Ed.), Nebraska Symposium on Motivation, 1981: Vol. 29. Response structure and organization (pp. 129-167). Lincoln: University of Nebraska Press.

Rachlin, H., & Green, L. (1972). Commitment, choice and self-control. Journal of the Experimental Analysis of Behavior, 17, 15-22.

Rachlin, H., Green, L., Kagel, J. H., & Battalio, R. C. (1976). Economic demand theory and psychological studies of choice. In G.H. Bower (Ed.), The psychology of learning and motivation: Vol. 10. (pp. 129-154). NY: Academic Press.

Schoenfeld, W. N., & Cumming, W. W. (1960). Studies in a temporal classification of reinforcement schedules: Summary and projection. Proceedings of the National Academy of Sciences, 46, 753-758.

Schroeder, S. R., & Barrera, F. J. (1976). Effects of price manipulation on consumer behavior in a sheltered workshop token economy. American Journal of Mental Deficiency, 81, 172-180.

Sherman, J. G. (1959). The temporal distribution of responses on fixed-interval schedules. Unpublished doctoral dissertation, Columbia University.

Sidman, M. (1960). Tactics of scientific research. NY: Basic Books.

Skinner, B. F. (1936). The effect on the amount of conditioning of an interval of time before reinforcement. Journal of General Psychology, 14, 279-295.

Skinner, B. F. (1953). Science and human behavior. NY: The Free Press.

Stebbins, W. C., Mead, P. B., & Martin, J. M. (1959). The relation of amount of reinforcement to performance under a fixed-interval schedule. Journal of the Experimental Analysis of Behavior, 2, 351-356.

Strauss, M. B. (Ed.). (1968). Familiar medical quotations. Boston: Little, Brown & Co.

Timberlake, W. (1984). A temporal limit on the effect of future food on current performance in an analogue of foraging and welfare. Journal of the Experimental Analysis of Behavior, 41, 117-124.

Timberlake, W., Gawley, D. J., & Lucas, G. A. (1987). Time horizons in rats foraging for food in temporally separated patches. Journal of Experimental Psychology: Animal Behavior and Processes, 13, 302-309.

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

Whaley, D. L., & Malott, R. W. (1971). Elementary principles of behavior. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Wilson, M. P. (1954). Periodic reinforcement interval and number of periodic reinforcement as parameters of response strength. Journal of Comparative and Physiological Psychology, 47, 51-56.

Winkler, R. C. (1970). Management of chronic psychiatric patients by a token reinforcement system. Journal of Applied Behavior Analysis, 3, 47-55.

Winkler, R. C. (1971). The relevance of economic theory and technology to token reinforcement systems. Behavior Research and Therapy, 9, 81-88.

Winkler, R. C. (1973). An experimental analysis of economic balance, savings and wages in a token economy. Behavior Therapy, 4, 22-40.

Winkler, R. C. (1980). Behavioral economics, token economies, and applied behavior analysis. In Limits to Action: The Allocation of Individual Behavior, pp. 269-297. NY: Academic Press.

Zeigler, H. P. (1976). Feeding behavior of the pigeon. In J. S. Rosenblatt, R. A. Hinde, E. Shaw, & C. Beer (Eds.), Advances in the study of behavior: Vol. 7. NY: Academic Press.

Zeigler, H. P., Green, H. L., & Lehrer, R. (1971). Patterns of feeding behavior in the pigeon. Journal of Comparative and Physiological Psychology, 76, 468-477.

Zeiler, M. (1977). Schedules of reinforcement: The controlling variables. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 201-232). Englewood Cliffs, NJ: Prentice-Hall, Inc.

VITA

Name: **Craig R. Loftin**

Address: 1631 Squaw Creek Road
Lander, Wyoming
(307) 332-4908

Language: English, maternal tongue; Spanish, fluent, written and spoken.

Education: Bachelor of Arts, Psychology, 1973
Central College, Pella, Iowa

Ph.D., Psychology, 1989
Utah State University,
Logan, Utah

Professional Activities:

1986-Present — Consultant - UNICEF
Guatemala Sub-Regional Office
Guatemala City, Guatemala

Responsibilities: Provide general assistance to the Sub-Regional Advisor for Childhood Disabilities in program development, implementation and evaluation in Central America.

Responsibilities: Program Evaluation Project. Provide training and technical assistance to Central American Technical Personnel and Project Coordinators in program evalution. This involves training in both formative and summative evaluation techniques.

Responsibilities: Child Development and Childhood Disabilities Personnel Training and Preparation Project. Design, coordinate the development of and evaluate a competency based teacher education program for early childhood and special education teachers. This is a sub-regional project and involves a cooperative effort of several governmental ministries and departments in Guatemala, Nicaragua and Honduras. The system being developed is a field-based training program that involves intensive on-site training of teachers on an individual and small-group basis. The system relies heavily on the use of the personalized systems of instruction approach.

Responsibilities: Teacher Training Center - Honduras and Guatemala
Design and assist in the development of a teacher training and technical assistance center for early childhood and special educators. The center will provide field-based group training and education to direct service staff through specialized training teams.

Responsibilities: Early Stimulation Program - Nicaragua
Provide training and technical assistance to the Ministry of Education, Department of Special Education, in the implementation of home-based early stimulation services for disabled children in this national program.

Consulting Psychologist -
Northwest Board of Cooperative Services
Thermopolis, Wyoming

Responsibilities: Conduct psychological, educational and behavioral evaluations of individuals aged five through adolescence. Plan, conduct and evaluate counseling and programming services for students of the District and members of their families. Conduct District-wide student achievement and assessment program. Consult with classroom teachers and aides regarding individualized programming for students. Develop and supervise the implementation of behavior and learning programs for students. Prepare grant proposals and applications. Coordinate Child Study Meetings, and IEP meetings.

1985-1987 School Psychologist -
Wyoming Indian Schools
(Fremont County School District #14).

Responsibilities: Conduct psychological, educational and behavioral evaluations of individuals aged five through adolescence. Plan, conduct and evaluate counseling and programming services for students of the District and members of their families. Conduct District-wide student achievement and assessment program. Consult with classroom teachers and aides regarding individualized programming for students. Develop and supervise the implementation of behavior and learning programs for students. Prepare grant proposals and applications. Coordinate Child Study Meetings, and IEP meetings. Serve as Chairman of the WIS Council for Excellence.

1984-1985 Psychology Staff -
Utah State University
Developmental Center for Handicapped Persons, Clinical Services Unit

Responsibilities: Conduct psychological, educational and behavioral evaluations of individuals aged birth through adolescence. Plan, conduct and evaluate counseling and programming services for outpatient clients of the unit. Supervise and train graduate psychology students during required applied behavior analysis internships.

1983-1984 Behavior Specialist -
Utah State University
Exceptional Child Center

Responsibilities: Conduct psycho-educational evaluations of special needs children with a variety of handicapping conditions, ages preschool through 15 enrolled in special educational classrooms in ECC and local school districts. Plan, supervise the implementaion of, and evaluate individualized and group behavior management and educational programs for these children. Conduct placement and in-service training for students and staff.

1982-1983 Research Assistant-
SAM Project

A microcomputer system to supplement secondary level mathematics curricula.

Responsibilities: Design, implement and analyze surveys to identify teacher instructional needs; design and write software documentation for use by teachers and software reviewers; design on-line teacher tutorial; assist in development and implementation of software field test, and project formative evaluation.

Resource Specialist -
UTAHS Project

A training and technical assistance project funded by the Administration of Children, Youth and Families, Head Start Bureau, to assist Head Start Programs in the state of Utah identify staff training and technical assistance needs in the area of early childhood education.

Responsibilities: Assist in the identification of administrative and direct service staff training and technical assistance needs; develop and implement training activities designed to meet identified needs; identify consultants who can assist programs meet needs; evaluate training and technical assistance activities; write grant proposals and quarterly and annual reports.

1980 - 1982 Director
Portage Project Home Start Training Center

A specific purpose grant, funded by the Administration of Children, Youth and Families, Region V Head Start to provide training and technical assistance in homebased, parent focused early education to Head Start programs in ACYF Region V.

Responsibilities: Write and coordinate preparation of grant/contract proposal and progress reports; prepare budgets, administer funds; plan strategies for meeting grant/contract objectives and monitor progress toward meeting those objectives; gather/analyze program data; recruite/hire/supervise training and direct service staff; identify staff training needs, execute training; coordinate program/materials development and field test; provide training and technical assistance to Head Start and other programs in ACYF Region V.

1979 - 1982 Coordinator
Operation Success and Model for Training programs.

A specific purpose contract with the Community Relations, Social Development Commission of Milwaukee, Wisconsin. This direct service Head Start program serves 120 families through home-based and classroom-based early childhood education.

Responsibilities: Write and coordinate preparation of contract proposal and progress reports; supervise staff comprised of two supervisors and ten teachers; supervise planning and conducting preservice and inservice training; evaluation of outcomes.

1979 - 1980 Training Specialist
Portage Project
Home Start Training Center (see above)

Responsibilities: Schedule training workshops, conduct needs assessments; develop training content/materials; conduct training workshops; evaluate outcomes; analyze agency follow-up materials; make recommendations; provide on-site technical assistance to programs; plan and conduct inservice training.

1976 - 1979 Project Training Coordinator
El Proyecto Portage

A specific purpose grant, funded by the Agency for International Development (AID) to provide Technical Assistance in home-based early intervention methodology in Latin America.

Responsibilities: Develop training curriculum and train personnel of the Peru Ministry of Education for implementation of a home-based intervention program for urban and rural Peru; provide technical assistance for modification of the Peru Initial Education Curriculum; supervise program implementation; report follow up for grant progress.

1973 - 1976 Home Teacher
Project PACE
Dubuque, Iowa

Responsibilities: Develop and implement individual educational plans for preschool-aged disabled children and their parents.

Training and Technical Assistance

1988 Prepare Discussion Paper "Central American Countries in Transition: Alternative Programming Approaches for the 1990s" for UNICEF GUA/AO - May.

Conduct evaluation of the Universal Primary Education and Literacy (UPEL) Project operated by the Ministry of Education of Nicaragua, and sponsored by UNICEF and UNESCO - October, November.

1986 Design and Implementation of a District-wide Personalized System of Instruction. The WISE Foundation, August, 1985 - May.

Conduct the evaluation of the Early Stimulation Project of the Ministry of Education of Nicaragua, Department of Special Education. Managua, Nicaragua - March.

Assist in implementation of recommendations made in the report 'A Descriptive Evaluation of the Early Stimulation Program of the Ministry of Education of Nicaragua, Department of Special Education'. Nicaragua, June and July.

Formualtion of a Compentency/Field-Based Training and Education System for Paraprofessional Service Delivery Personnel. UNICEF, Guatemala, June.

Participated in the development of the the three-year plan for Child Disability Projects for UNICEF in Honduras, September.

Conducted a three week workshop on the "Development, Implementation and Evaluation of a Personalized System of Staff Development" for Child Disability Project Personnel in Nicaragua, Honduras and Guatemala, in Guatemala City, September and October.

Initiated the development of a "Personalized System of Staff Development" for the professional and paraprofessional staff of the Early Stimulation Program in Nicaragua, October and November.

1985 "Adaptation and National Institutionalization of the Staff Development System," (a functional product of the experimental implementation of the Model for Staff Training and Supervision - see 1983 below.) The Ministry of Education of Peru, Lima, Peru, March through August, 1985.

"Home-based Early Education and Parent Education," UNICEF, Managua, Nicaragua, February, 1985.

1984 "Evaluation of the Technical-Pedagogical aspects of the Project 'Early Education as an Incentive for Community Development'," The Agency for International Development, Lima, Peru, 1984

Agency for International Developement, Lima, Peru', Education, Health and Nutrition Division, 1983-84.

1983 "Development of a Model for Staff Training and Supervision for the Project 'Early Education as an Incentive for Community Development'," The Agency for International Development, Lima, Peru, 1983.

Nonformal Education Field Technical Support, Creative Associates, Washington, DC, May, 1983.

1981 Servicio, Educacio'n y Rehabilitacio'n, Inc., Milwaukee, Wisconsin, Thelma Martinez, Director of Education, June, 1980, June, 1981.

Indiana Department of Public Instruction, Division of Bilingual/Bicultural Education, Indianapolis, Inc, Mina Iden, Coordinator, December 1979, June, 1980, June, 1981.

1980 "Design and Implementation of a Home-Based Program for Handicapped Preschoolers," The Peace Corps, ACTION, Quito, Ecuador, 1980.

1979 "Mainstreaming the Handicapped Child Into the Preschool Classroom," Branch County Head Start, Coldwater, Michigan, 1979.

"Individualization Within the Preschool Classroom," Child Inc., Austin, Texas, 1979.

Escuela de Retardo Mental, Centro de Rehabilitacio'n, Santo Domingo, Dominican Republic, Isabel Meyreles T., Directora, April, 1979, October, 1979.

1978 "Servicios Para Nin~os Desventajados en un programa con Base en el Hogar," Fundacio'n de Asistencia Para Nin~os y Adultos con Retardo Mental, Guayaquil, Ecuador, 1978.

1979-1981 "Training and Technical Assistance to Home-Based Programs," provided through the Portage Project Home Start Training Center to the Following agencies from 1979-1981:

This training and technical assistance consisted of one or more of the following activities designed to assist public and private agencies implement early childhood education services:

a. program needs assessment,
b. training needs assessment,
c. providing necessary training to direct service and administrative staff, and
d. evalution of staff efforts.

University of Cincinnati -
Arlitt Child Development Center
Cincinnati, Ohio.

Council for Economic Opportunity in Greater Cleveland,
Cleveland, Ohio.

Pickaway County Community Action Organization, Inc.,
Circleville, Ohio.

Community United Head Start,
Cleveland, Ohio.

Miami Valley Child Development Centers, Inc.,
Dayton, Ohio.

Montogomery County Community Action Agency,
Dayton, Ohio.

WSOS Community Action, Inc.,
Fremont, Ohio.

Knox County Head Start,
Mt. Vernon, Ohio.

Licking Economic Action Development Study,
Newark, Ohio.

Toledo Head Start,
Toledo, Ohio.

Coshocton County Head Start,
Coshocton, Ohio.

Monroe County CAP, Inc.,
Bloomington, Indiana.

Community Action Program of Evansville,
Evansville, Indiana.
Lake County EOC, Inc., Hammond, Indiana.

South Lake County Head Start,
Crown Point, Indiana.

EOC of Daviess, Greene, Know, and Sullivan County, Inc.,
Vincennes, Indiana.

Northeast Michigan Community Service,
Alpena, Michigan.

City of Holland School District
Holland, Michigan.

Capital Area Community Service
Lansing, Michigan

Tri-County Council for Child Development
Decatur, Michigan.

Washtenaw County Head Start Program
Ypsilanti, Michigan.
Branch County Head Start
Coldwater, Michigan.

Monroe County Opportunity Program
Monroe, Michigan.

Central Wisconsin CAC
Wisconsin Dells, Wisconsin.

Dane County Head Start Parent Council
Madison, Wisconsin.

Kenosha Head Start
Kenosha, Wisconsin.

Jefferson County Special Education
Jefferson, Wisconsin.

Child and Family Development Center
Milwaukee, Wisconsin.

Day Care Services for Children
Milwaukee, Wisconsin.

Milwaukee Public Schools Head Start
Milwaukee, Wisconsin.

Guadalupe Head Start/Council for the Spanish Speaking
Milwaukee, Wisconsin.

Next Door Foundation
milwaukee, Wisconsin

West Central Preschool Education Program
Glendwood City, Wisconsin.

Western DAiryland
Whitehall, Wisconsin.

South Wood County Child CAre Center, Inc.
Wisconsin Rapids, Wisconsin.,

Clay-Wilkin Opportunity Council
Moorehead, Minnesota.

Goodhue-Rice-Wabasha Council
Zumbrota, Minnesota.

Mahube Community Council
Detroit Lakes, Minnesota.

Wright County Community Action
Waverly, Minnesota.

Minnesota Valley Action Council, Inc.
Mankato, Minnesota.

Southwest Minnesota Opportunity Council
Worthington, Minnesota.

Western Community Action, Inc.,
Marshall, Minnesota.

College of Human Resources,
Southern Illinois University,
Carbondale, Illinois.

Department of Human Services
Children and Youth Services Division
Chicago, Illinois.

Vermilion-Champaign-Iroquois County Head Start
Danville, Illinois.

Northwestern Illinois CAA Head Start
Freeport, Illinois.

Rockford Department of Human Resources CAP
Rockford, Illinois.

Conference Presentations:

"A Home-Based Early Intervention Model: Project PACE," Iowa State Association of Mental Retardation, Annual Conference, May, 1975.

"Behavior Analysis: A Training Model," First National Conference on Behavior Analysis, Chincha, Peru, November, 1977.

"The Portage Project," the Dominican Association of Mental Retardation, Santo Domingo, Dominican Republic, February, 1978.

"Evaluating Your Home-Based Program Along Three Continua: Program, Staf and Child Progress," Region V Head Start Association Conference, Indianapolis, Indiana, November, 1979.

"Evaluating Your Home-Based Program Along Three Continua: Program, Staff and Child Progress," XV National Head Start Association Conference, Miami, Florida, May, 1980.

"Toward a Model Approach to Staff Training and Evaluation," XV National Head Start Association Conference, Miami, Florida, May, 1980.

"Serving Handicapped Children in Home-Based Head Start," Resource Access Project Conference, University of Minnesota, Bemidji, Minnesota, February, 1981.

"Serving Handicapped Children in Home-Based Head Start," Resource Access Project Conference, Mankato State University, Mankato, Minnesota, February, 1981.

"Staff Evaluation and Development," XVI National Head Start Conference, Home-Based Day, Los Angeles, California, May, 1981.

"Teaching Parents to Teach Their Preschoolers at Home," First Annual Conference on Parent Training, University of Texas at Arlington, Texas, September, 1981.

"The Importance of Dad: The Father's Role in the Growth and Development of the Young Child," presented at Wisconsin Conference on Families: A Family Affair: Myths and Realities, Portage, Wisconsin, November, 1981.

"The Role of Verbal Mediation in Human Performance on FixedInterval Schedules of Reinforcement," presented at the Northern Rocky Mountain Educational Research Association Conference, October, 1983.

"A National Model for Preschool Staff Training and Supervision," presented at the Northern Rocky Mountain Educational Research Association Conference, November, 1984.

"An Experimental Analysis of Resurgence," presented at the Association for Behavior Analysis, May, 1985.

"Early Childhood Special Education and the Portage Model in in Latin America," Invited Paper, 1988 International Portage COnference in Tokyo. Tokyo, Japan, July, 1988.

Publications and Reports:

Loftin, C.R. (in press). Early Childhood Special Education and the Portage Model in Latin America. In Yamaguchi, K. (Ed.) International Contributions of the Portage Project to Special Education, Tokyo: Shufunotomo.

Loftin, C.R. (1988). "A Rapid Appraisal of the Universal Primary Education and Literacy Project in Nicaragua." UNICEF, GUA/AO.

Loftin, C.R. (1988). "Central American Countries in Transition: Alternative Programming Approaches for the 1990s." UNICEF, GUA/AO.

Loftin, C.R. (1986). "A Descriptive Evaluation of the Early Stimulation Program of the Ministry of Education of Nicaragua, Department of Special Education." UNICEF, Nicaragua.

Myers, R., Hidalgo, E., Loftin, C., Karp- Toledo, E., Llanos, M., Valdivieso, E., Vigier, M.E., Pawlikowski de Ferrari, C., Engle, P., (1985). "Pre-school Education as a Catalyst for Community Development- An Evaluation." United States Agency for International Development, Lima, Peru.

Shearer, D., and Loftin, C. R. (1984). "Teaching Parents to Teach Their Preschooler at Home," in Parent Training, R. Polster (Ed.). New York: Guilford Press.

Loftin, C.R. (1982). The Home Visitor Observation and Assesssment Scale. Child Development Associate Resource Center, University of Illinois, Champaign, ERIC Document.

Loftin, C.R. (1981). "The Home Visit: Implementation", in Boyd, R. and Herwig, J. (Eds). Serving Handicapped Children in Home-Based Head Start, Administration of Children, Youth and Families, Department of Health and Human Services, Washington, DC.

Cochran, D., and Loftin, C.R. (1980). "The Portage Model in the Head Start Home-Based Option," Portage Project Readings. Portage: Cooperative Educational Service Agency #12.

Jesien, G., Loftin, C.R., et al. (1979). Informe Final del Proyecto "Validacio'n del Modelo Portage." Ministerio de Educacio'n del Peru', Lima, Peru', 1979. Published simultaneously in English and Spanish by Cooperative Educational Service Agency #12, Portage, Wisconsin.

Gonzalez, A., Loftin, C.R., et al (1979). Estructura Curricular Ba'sica de Educacio'n Inicial, PRONOEI-BH. Ministerio de Educacio'n del Peru', Lima, Peru'.

Loftin, C. R. and Rodriquez, R. (1978). Informe Te'cnico de la Primera y la Segunda Concentracio'n de Entrenamiento Para el Programa No-Escolarizado de Educacio'n Inicial Con Base en el Hogar, Coopertive Educational Service Agency #12, Portage, Wisconsin.

Community Service and Organizational Membership (current):

President, Wind River Council for Exceptional Children.

Member, Association for Behavior Analysis.

Member, Society for the Advancement of Behavior Analysis.

Member, Council for Exceptional Children.

Member, Association for Childhood Education International.