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MASSAD, PHILLIP MICHAEL

THE ECONOMIC EFFECT OF DIFFERENT REINFORCERS ON THE CONSERVATION MODEL

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THE ECONOMIC EFFECT OF DIFFERENT REINFORCERS ON THE CONSERVATION MODEL

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PHILLIP MICHAEL MASSAD

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THE ECONOMIC EFFECT OF DIFFERENT REINFORCERS ON THE CONSERVATION MODEL

APPROVED BY

DISSERTATION COMMITTEE

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A PH.D. is more of a transformation than a degree. Throughout this sojourn, one is touched by many people who shape one's thinking or who provide inspiration in other ways. It seems all too inadequate and too traditional to ennumerate them, catloguing the special graditudes. Nevertheless, it is an endeavor that must be done, and one that I perform with the greatest of pleasure.

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Abstract

Following a baseline session, human subjects were allowed to choose between concurrently available games contingent upon a fixed amount of bar pressing. It was assumed that the total amount of a dimension apportioned to bar pressing and game playing is conserved between baseline and contingency sessions. Conservation theory was shown to be moderately successful in predicting game choices. The results are also discussed in terms of economic demand theory. Elasticity of demand (defined in operant terms as the ratio of the percentage change in contingent responding per session relative to the percentage change in the instrumental response requirement) is considered as a function of the degree of substitutability of the contingent responses (games). These economic variables are discussed in relation to psychological choice behavior.

The Economic Effect of Different Reinforcers on the Conservation Model

Thorndike's original law of effect has changed little since 1911; reinforcement is still defined as a procedure by which a response is increased in probability, vigor, or frequency as a result of the response being followed by a stimulus. Stimuli which have such an effect on responses are called reinforcers. Yet, this traditional definition of reinforcement has proved to be a problem in the psychological literature (see Mackintosh, 1974). For example, there is a degreee of circularity in this approach since the law of effect is not stated to allow _a priori_ predictions concerning the ability of a particular stimulus to strengthen a particular response.

In a well-known article, Meehl (1950) suggested that the law of effect could avoid the circularity problem if reinforcers were transituational in their effects. Such an approach, however, requires a potentially prodigous effort in cataloguing the events which increase instrumental responses. In addition, many reinforcers work well under one set of conditions, but not under others (Breland & Breland, 1961). Most researchers have preferred to discover an event's reinforcing attributes rather than listing all events in some kind of "seed-catalogue" fashion. Consequently, several theories of reinforcement have evolved to distinguish the process of reinforcement from predicting whether a particular stimulus will come to control a particular response.

Hull's Theory of Reinforcement

Hull (1943) made one of the earliest attempts to resolve the issue of why and how reinforcement works. The crux of his theory rested upon physiological need reduction as the basis for reinforcement. For example, food serves to strengthen a response because it satisfies a need state of the organism. Problems with the need-reduction approach quickly surfaced when the reinforcement capacities of nonnutritive substances were demonstrated. For example, Sheffield and Roby (1950) found that food deprived rats would learn a discrimination task when the reward was saccharine. Such artificial sweetners are virtually unmetabolized and provide no nourishment value. Consequently, Hull was forced to modify his definition of reinforcement.

Hull's (1952) later approach replaced need reduction as the basis for reinforcement with a reduction in the drive stimuli generated by a need state. For example, an organism's hunger drive gives rise to various motivational stimuli, (roughly speaking, the feeling of being hungry), the reduction of which acts to reinforce behavior. This tension-reduction approach would appear to be seriously undermined by examples of apparently frustrating events acting to strengthen behavior. For instance, rats will continue to traverse an alley for the opportunity to engage in copulation even when interupted by the experimenter prior to ejaculation (Sheffield, Wulff, & Backer, 1951). There are also reports (e.g., Butler, 1953) of animals performing a task in order to obtain the opportunity merely to view another organism confined in an adjacent cage. This action would seem to be due to drive induction rather than drive reduction. These and other problems have been well documented (e.g., Bolles, 1976), casting doubt on Hull's approach as _the_ answer to why and how reinforcement works.

Consumatory Response Theory

An alternative approach to drive reduction as the basis of reinforcement has been to regard rewards as responses rather than stimuli. That is, the _act_ of eating may be considered a reward rather than the substance being eaten. This approach ascribes rewarding capacities to certain acts and the sensations accompanying them. The advantage of this approach, relative to a need-reduction schema, is that the consumption of nonnutritive substances can now be considered rewarding. The consumatory response hypothesis faces serious difficulties, however, in the light of evidence showing that reinforcement can be achieved even though the response is by-passed altogether. For instance, a rat will learn to press a lever that leads to an injection of food (see Rachlin, 1976) or intracranial stimulation (Olds & Milner, 1954). Despite these drawbacks, David Premack (1965, 1971) has adopted the use of responses as reinforcers in his own unique theory of reinforcement.

Premack's Theory of Reinforcement

Premack's theory focuses on a hierarchy of responses, ordered according to value, that occur in any given situation. None of these responses have unique characteristics. For example, reading a book, watching television, gardening, etc. are events that may be ordered on a hierarchy of value. According to Premack (1965), for any pair of responses in that hierarchy, the more-probable one will reinforce the less-probable one. Hence, when an event more probable in the hierarchy is contingent upon the occurrence of an event lower in the hierarchy, the higher event serves to increase the frequency of the lower event

(Rachlin, 1976). For example, assume that watching television is more probable in the hierarchy than gardening. If the opportunity to view television were contingent upon gardening, the frequency of the occurrence of the gardening would be increased.

The manner in which the value for two events is determined is via a free-baseline situation in which a pair of responses are available to a subject free of constraints, excepting the availablity of time limited by the experimenter. According to Premack, time devoted to one activity and the other is proportional to the value of those responses. The implication is that _any_ response may serve as a reinforcer or as an instrumental repsonse, depending on its probability in relation to the occurrence of other behaviors. Hence, this _probability-differential_ hypothesis would appear to escape the problem of circularity inherent in the law of effect by designating the more probable response as the reinforcer. Nevertheless, an objection could be raised concerning Premack's assumption that the free-baseline procedure lacks constraints. Although the baseline situation may _appear_ to be independent of constraints, the reality of being able to engage in only one response at a time, over a limited duration, is a very serious constraint on the free baseline situation. The problems with Premack's view require more elaboration, but for purposes of this dissertation, these may suffice.

Response Deprivation and Conservation

Timberlake and Allison (1974) have extended Premack's notion that responses serve as reinforcers. Their adaptive model assumes that instrumental performance is a conflict between freely occuring behavior and restrictions of a schedule. According to the response deprivation hypothesis, a response will be an effective reinforcer if the schedule results in that response being suppressed below its baseline level. This relationship may be expressed as:

$$I/C > O_i/O_c \qquad (1)$$

where the ratio of instrumental responding (*I*) and the contingent responding (*C*) must be greater than the same ratio when both responses are freely available. The terms O_i and O_c represent the baseline amount of instrumental and contingent responses, respectively. If the subject does not perform the instrumental reponse as specified by the schedule, the amount of time engaged in the contingent response during the schedule period will necessarily be less relative to its baseline level. For example, a rat may spend three seconds pressing a bar (O_i) and 50 seconds eating (Q_c) during a free-baseline situation. Under the restrictions of a particular contingency session, a rat may press the bar for 35 seconds (*I*) and eat for 15 seconds (*C*). Putting these numbers into Inequality (1) gives us:

$$35/15 > 3/50$$

which is true. This means that the definition of response deprivation is satisfied (inequality (1) is true), therefore the bar press response should increase over its baseline level.

The response deprivation hypothesis differs from Premack's probability-differential hypothesis in that the response deprivation condition determines instrumental performance rather than the probability differential between two responses. The response deprivation hypothesis places no particular importance on the position of a response in a free baseline hierarchy. Response *X*, whether it ranks above or below Response *Y* in the baseline response hierarchy, can serve to strengthen *Y* provided that the chosen reinforcement schedule suppresses Responses *X* below its baseline level (e.g., when Inequality 1 is true).

Allison and Timberlake (1974) have presented an example of their response deprivation hypothesis. In one experiment, it was first shown that rats spent more time licking a .4% saccharine solution than a .3% solution when paired in a baseline session. This baseline phase was followed by contingency sessions in which consumption of the .4% and .3% solutions were the instrumental and contingent responses, respectively. The employed schedule satisfied the response deprivation requirement and produced an increase in .4% licking relative to its baseline measure. Contrary to Premack's position, this provides a clear example of a less frequent response reinforcing a more frequent response.

Allison (1976) has recently modified the deprivation approach, introducing the notion of response conservation. In essence, the response conservation model asserts that if the instrumental and contingent responses are considered together, the total amount of some dimension attributable to the two responses is conserved by the subject as between a baseline session and contingency session. As stipulated by Allison (1976), the dimension conserved is actually unit-free; however, to promote understanding, it may be convenient to think of the dimension conserved as being energy expenditure. For example, if a rat were required to press a bar to obtain water, it may be that one lever press requires four times as much energy expenditure as one lick. Thus defined, the total amount of this energy dimension apportioned to this pair of responses should be conserved across various reinforcement schedules.

Tests of the conservation model have employed a variant of the typical FR-schedule. In using what has been called a *cumulative duration schedule* (Shettleworth, 1975), the subject is required to engage in the instrumental and contingent responses for a specified duration. For example, a rat may be required to run in a wheel for 10 seconds to gain access to a drinking tube for 20 seconds. Unlike a typical FR-schedule, the cumulative duration schedule requires the subject to engage in the contingent response for a specified period of time before the instrumental activity again becomes available. In contrast to a FI-schedule, a specified amount of both responses is required. In short, there is a continuous cycling between the instrumental and the contingent response that requires the organism to engage in one activity for a given time in order to subsequently engage in the other. In the above example, upon completion of the instrumental requirement, the running wheel would lock until the rat drank for 20 seconds, at which time the wheel would unlock and the drinking tube would be removed. The number of times that the subject completed the *I* and *C* sequence in a fixed session length is the dependent variable (*N*).

The conservation model for a cumulative duration, fixed-ratio schedule can be expressed as:

$$N(kI + C) = kO_i + O_c \qquad (2)$$

where *I* and *C* are the instrumental and contingent responses specified by the schedule while O_i and O_c are their baseline counterparts. The unit-free *k* parameter is defined as the amount of the dimension entailed in performing one unit of response *i*, relative to the amount entailed in performing one unit of response *c*.

To better understand the role of the *k* parameter, consider the following hypothetical example. Suppose a rat is required to press a lever for access to a drinking spout, and the dimension conserved between these two responses is energy expenditure. The *k* parameter represents the amount of energy dimension entailed in performing one lever press relative to the amount of the energy dimension entailed in 1 second of drinking.

Recently, the conservation model has been extended to concurrent fixed-ratio schedules (Shapiro & Allison, 1978). The concurrent schedule allows a choice between two alternative fixed-ratio components. The subject has an initial choice of selecting either of two instrumental responses (I_1 or I_2). Once this selection has been made, completion of the instrumental response will lead to the availability of the appropriate contingent response, C_1

or $\underline{C}_2$. After the subject completes the contingent response requirement, as specified by the cumulative schedule, the choice between the instrumental response will be made again.

An initial choice of either instrumental response (e.g., $\underline{I}_1$) excludes responding to the other instrumental response ($\underline{I}_2$) and contingent response ($\underline{C}_2$) until the requirements for $\underline{I}_1 + \underline{C}_1$ (Component 1) are completed. Component 1, having $\underline{I}_1$ as the instrumental response requirement followed by $\underline{C}_1$ of the contingent behavior results in the dependent variable $\underline{N}_1$ which is the number of times Component 1 is selected. Similarly, Component 2, with $\underline{I}_2$ as the instrumental response, followed by $\underline{C}_2$, the contingent response, has $\underline{N}_2$ as the dependent variable. For example, a rat may have the choice of pressing one bar for 10 seconds ($\underline{I}_1$) to be able to eat for 30 seconds ($\underline{C}_1$) or pressing a different bar for 5 seconds ($\underline{I}_2$) to be able to eat for 15 seconds ($\underline{C}_2$). If one bar press response is chosen over another (e.g., $\underline{I}_1$, 10 sec, instead of $\underline{I}_2$, 5 sec), the second component of bar pressing and eating (e.g., $\underline{I}_2 + \underline{C}_2$) becomes unavailable until the subject completes the specified amount of responding on the selected component (e.g., $\underline{I}_1 + \underline{C}_1$). After completing the selected component, the subject once again is presented a choice between both components.

The model for a concurrent fixed-ratio (cumulative duration) can be expressed as:

$$N_1(kI_1 + C_1) + N_2(kI_2 + C_2) = kO_i + O_{ci} \quad (3)$$

N_1 and N_2 designate the number of times the subject executes the respective components. Again, *k* represents the amount of the dimension entailed in performing one unit of response *i* relative to one unit of response *c*. This dimension is assumed to be conserved between the two responses across sessions.

To date, the conservation model has received impressive empirical support (e.g., Allison, 1976; Shapiro & Allison, 1978; Allison, et al., 1979). However, the model has yet to be tested using two *different* contingent respones. Previous studies have used the same contingent response, varying only the instrumental response duration for both components of the concurrent schedule. Among other purposes, the present study is an attempt to fill this gap in the literature. The conservation model will also serve as a heuristic device, in the present study, to test applications of another theory--the economics of demand.

Economics Applied to Psychology

Recently, there have been a number of attempts to cast various aspects of operant choice behavior within an economic framework (e.g., Battalio, Kagel, Winkler, Fisher, Basmann, & Krasner, 1974; Lea & Roper, 1977; Rachlin, Green, Kagel, & Battalio, 1976). A typical analogy consists of relating what economists call a _demand curve_ to its psychological analogue. The demand curve relates the purchased amount of a commodity to its price. The obvious psychological counterpart is the relationship between the number of reinforcements obtained (quantity purchased) and the requirements of a schedule of reinforcement, e.g., its price (Lea, 1978).

Despite these similarities, the analogy between price and schedule parameters is not without complications. One difficulty in extending operant principles to economic terms deals with the kind of schedule used as a price analogue. A fixed-ratio schedule requires that a subject "pay" for a reward by performing a specified number of responses. This kind of schedule is not translated easily into a money analogue in that the subject operates under lesser budget contraints by being able to generate responses at will. Money, on the other hand, can not be generated in the same manner as bar presses; hence, responses "paid" as a requirement of a ratio schedule are more easily replenished than is money spent. Typical concurrent _interval_ schedules are an ineffective analogue as well, in that the time spent engaging in the instrumental response can be counted simultaneously toward the completion of two schedules. That is, as time passes, the moment of reinforcement advances for both schedules and time that is counted toward the completion of one schedule can also be counted toward the completion of another schedule; hence, there is no effective budget constraint.

The conservation model offers a solution to the foregoing price problem by utilizing the cumulative duration schedule. This type of schedule makes the budget constraint problem more tractable. Since any experimental session is limited in duration, a schedule that requires the subject to engage in a response for a specified duration avoids the budget constraint problem of the fixed-ratio schedule. Furthermore, by limiting the subject's responding to only one response at time, the budget constraint problems of an interval schedule are circumvented.

It is suggested that the procedure of the conservation model offers possible alternatives to make for a more straightforward analogy between economic and operant principles than has previously existed. Economic demand theory may also offer equally important contributions to the advancement of the conservation model. The question of how the conservation model deals with different reinforcers can now be viewed from an economic framework.

In economics, the functional relationship between the quantity of a commodity that is purchased and its price is measured by an index known as elasticity. Elasticity (*e*) can be defined as:

$$e = -(\Delta Y/Y)/(\Delta X/X) \qquad (4).$$

This measure reflects the amount of a commodity, *Y*, purchased in response to a change in price, *X*. The minus sign in Equation (4) is inserted to make the elasticity number nonegative. It is assumed that a rise in price (ΔX positive) will lead to a fall in quantity demanded (ΔY negative) so that the numerator and denominator will be of opposite sign (Baumol, 1972). Elasticity is usually expressed as one of three categories: *unit*, *elastic*, or *inelastic*. Unit elasticity is demonstrated when a percentage change in price, *X*, results in an identical percentage change in amount of *Y* purchased, thus leaving total expenditure unchanged and the absolute value of *e* equaling 1. For example, in the case of unit elasticty, the price of Bourbon (*X*) may increase by 3% and, correspondingly, the purchase of Bourbon would decrease by 3% (*Y*). An elasticity less than 1, known as inelastic demand, would occur if a change in the cost of Bourbon (e.g., 3% increase) was proportionately larger than the change in purchase (e.g., 2% decrease) so that the actual total expenditure increases. Finally, elastic demand (e > 1) would occur if the purchase of bourbon decreased (e.g., 4% drop in sales) disproportionately to an increase in price (e.g., 3%). Elasticity is independent of the units in which quantity and price are measured; hence, changes in "consumption" of qualitatively different reinforcers can be compared as prices increase. Before addressing the question of elasticity as a function of concurrent choices of a different nature, additional considerations must be dealt with.

The elasticity of demand in animal studies has been shown to be a function of the substitutability of reinforcers (e.g., Hogan, Kliest, & Hutchings, 1970; Lea & Roper, 1977; Shettleworth, 1972) Substitutable concurrent sources of reinforcers (e.g., root beer and Tom Collins mix) have shown greater elasticity relative to less substitutable reinforcers (e.g., food and root beer) as a function of price increases for one member of the commodity pair (Kagel, Battalio, Rachlin, Green, Gasmann, & Klemm, 1975). For example, since two sweet drinks are intuitively more substitutable for each other than are water and food, increasing the price of root beer will decrease its "purchases" (demonstrating elasticity), and increase the consumption of Tom Collins mix. On the other hand, the subject would be less inclined to purchase a less substitutable alternative to root beer (e.g., food), thereby demonstrating inelasticity, or at least less elasticity.

Most pairs of responses or commodities would be somewhere between the extremes of complete substitutablity and complete nonsubstitutability. Seemingly nonsubstitutable items such as food and clothing may be substitutable to a certain extent. Food is substitutable for clothing to the extent that food provides warmth when eaten in large quantities (Rachlin et al., 1976). A pair of responses or commodities may be more accurately described as differing along a continuum of substitutability than being considered as substitutes and nonsubstitutes. However, for convenience, a pair of responses that are less substitutable than another pair of responses will be termed nonsubstitutes and substitutes, respectively.

The conservation model can be adapted to deal with qualitatively different reinforcers to test the hypothesis that a certain dimension is conserved across schedule changes for both substitutable and nonsubstitutable responses. The conservation model, using a concurrent schedule of different contingent responses but identical instrumental responses differing only in duration, would be expressed as:

$$N_1(I_1 + k_1C_1) + N_2(I_2 + k_2C_2) = O_i + k_1O_{c1} + k_2O_{c2} \quad (5)$$

In this formula the fitting constants, k_1 and k_2, are now associated with response c, in contrast to earlier formulations assigning k to response i. This is done in order to scale two different responses, c_1 and c_2, relative to identical responses, i_1 and i_2, thereby providing a common means of comparison.

The demand for response C_1 or C_2, as a function of its own price, I_1 or I_2, has been referred to thus far as elasticity, but is more strictly <u>own-price</u> elasticity (Lea, 1978). The own-price elasticity equation for both contingent responses, separately, can be derived from the following equation provided by Samuelson (1974):

$$e = -\{\Delta Q_2/[(Q_1 + Q_2)/2] \div \Delta P_2/[(P_1 + P_2)/2]\} \quad (6)$$

where Q_1 and Q_2 is the quantity of good demanded across two periods of time or price levels. P_1 and P_2 are the price levels fixed at different times. Each change in P is related to the average P, namely $(P_1 + P_2)/2$, and the change in Q is related to the average Q, namely $(Q_1 + Q_2)/2$. To apply the elasticity measure to the conservation model, consider the following example. Suppose a concurrent schedule provides a choice between licking a saccharine tube (C_1) or eating food pellets (C_2) and requires the subject to press a lever (I_1 or I_2) to obtain access to either response. As the instrumental response requirement increases (I_3 or I_4), the response of licking the saccharine tube and eating food pellets is termed C_3 and C_4, respectively. Letting $Q=NC$ (amount of time spent engaged in response C) and $P=I$ (the instrumental response requirement to gain access to the contingent response) the own-price elasticity formula can be rewritten as:

$$-\Delta NC/[(NC_1 + NC_3)/2] \div \Delta I/[(I_1 + I_3)/2] = \text{own price elasticity} \quad (7).$$

NC_1 and NC_3 represent the amount of time spent in licking the saccharine tube under the two different reinforcement schedules with instrumental response requirements, I_1 and I_3, respectively.

Cross-price elasticity would reflect the change of the consumption of eating food pellets as a function of the instrumental requirement for licking the saccharine tube. The cross-price formula can be expressed as:

$$\Delta NC/[(NC_2 + NC_4)/2] \div \Delta I/[(I_1 + I_3)/2] = \text{cross-price elasticity} \quad (8)$$

where NC_2 and NC_4 would represent the amount of time spent in eating food pellets as a function of the "price" changes (I_1 and I_3) associated with the alternative response of licking the saccharine tube.

The measure of elasticity used in conjunction with the conservation model provides an application of economic demand theory on two acccounts. First, the elasticity of demand for a single response should be greater with a substitutable alternative relative to a nonsubstitutable one. The present experiment will attempt to test this prediction in the context of a human-choice situation using two different sets of games as substitutable and nonsubstitutable pairs of recreational activities. The opportunity to engage in the substitutable and nonsubstitutable game sets will be controlled through an instrumental response requirement of bar pressing. The bar pressing requirement serves as a price analogue and increases for only one member of the game pair over the course of the experiment. It is predicted that the demand for this member of the game pair will be more elastic for the substitutable than nonsubstitutable condition due to the more similar alternative available.

Since demand is a function of price, larger increases in price should act to decrease demand more than a smaller increase. The present experiment will explore this hypothesis by varying the magnitude of the instrumental response requirement (e.g., low and high rate increases for bar pressing across training sessions) to engage in the contingent responses (games).

Lastly, consistent with the conservation model, it is predicted that subjects will conserve the total amount of the dimension apportioned to Response $\underline{i}$ and responses $\underline{c}_1$ and $\underline{c}_2$ across the baseline and contingency sessions. More specifically, the conserved dimension associated with the bar press and game responses should remain more or less constant as the instrumental requirement (price) of a single member of the game pair increases. The parameter respresenting the conserved dimension ($\underline{k}_i$) coupled with baseline and contingency parameters measured experimentally, will enable the model to predict either dependent variable (e.g., $\underline{N}_1$ or $\underline{N}_2$), given the numerical value of the other dependent variable.

Experiment 1

Method

Subjects. Forty-eight subjects, enrolled in an Experimental Psychology course, participated in order to fulfill partial requirements for a course. Data of two subjects from a control group and one from an experimental group were replaced due to a computer malfunction.

Apparatus. Two levers mounted on the opposite ends of a table served as the instrumental response manipulanda. When depressed, the levers initiated separate timers on a SWTP 6800 microcomputer system. The substitutable, contingent responses consisted of two games played on identical units (*Merlin*) manufactured by Parker Brothers Co. Subjects were instructed to play a game known as *Mindbender* on one unit and a game known as *Echo* on the other. The *Mindbender* game required subjects to use a process of trial and error to solve for a pattern of numbers selected by the game unit, thus requiring short-term retention of their responses in order to solve a single game. The game *Echo* also required short-term memory in order to mimic a series of lights and tones on the unit's display. Since both games shared the use of short-term memory, they were intuitively designated as substitutes.

The nonsubstitutable response pair consisted of the games *Mindbender* and *TV Bowling*. The latter game is one of several available from the Home TV Programmer Studio II manufactured by RCA. In constrast to *Mindbender* which requires short-term memory, *TV Bowling* required the subject to exercise hand-eye motor coordination to operate the game's control unit that moved a bowling ball down the alley on the TV screen in order to knock down the bowling pins. To operate each game, a switch on a "power-box" attached to each game had to be moved to an "ON" position. These switches controlled the power supplied by the microcomputer and initiated independent timers recording the duration of responding to each game. Each lever-press and power-switch manipulandum contained two lights, green and red, to serve as a signal for the response's availability and nonavailability, respectively.

Design. The present experiment consisted of a 2 (game pair: substitutable or nonsubstitutable) X 3 (price shift: high, low, or control) X 5 (sessions: Baseline 1, Contingencies 1-3, and Baseline 2) design. Subjects were randomly assigned, 8 per group, to one of six treatments according to the type of game pair and magnitude of price shift across sessions: (1) substitutable/low shift (SL), (2) substitutable/high shift (SH), (3) substitutable/control (SC), (4) nonsubstitutable/low shift (NL), (5) nonsubstitutable/high shift (NH), and (6) nonsubstitutable/control (NC). The dependent variables consisted of own- and cross-price elasticity measures in addition to the number of times each game was selected. In addition, a questionnaire was given upon the conclusion of the experiment, asking subjects to indicate how similar the games were along a 5 point continuum, with 1 being very similar and 5 very dissimilar.

Procedure.

Paired Baseline. Each subject was seated in front of the four manipulanda--the two lever presses and power-switch/game-set combinations. The subjects were instructed:

> Before you are four response alternatives--two lever presses and two power-switches which control the game units (The experimenter pointed to each of the items, demonstrated the use of the lever presses and games, and then allowed the subject to play each of the games for approximately 1 min). You may respond to any of the four alternatives when their green light is illuminated. You can not respond to an alternative if its red light is illuminated. Please remain seated throughout the experiment. Do you have any questions about these directions?

The onset and offset of the 15 min baseline session was signalled by a short 0.5 sec and 2.0 sec tone, respectively. At the onset of each baseline session all four manipulanda signalled availability via illumination of the green lights. Access to the responses was maintained for one-minute discrete trials. At the end of each minute the manipulanda signalled unavailability for 3 sec and the response durations for each alternative were recorded by the microprinter before the cycle continued.

Contingency sessions. The baseline session was followed immediately by an initial contingency session. In this session, game participation was contingent upon the subject depressing the lever for 1 sec before gaining access to either game. At the start of each contingency session, the subject was to respond to one of two lever presses (I_1 or I_2). Once the subject responded to either of the lever presses (e.g., I_1), the other lever press (e.g, I_2) became unavailable for responding until the subject completed the instrumental and contingent response requirements on the chosen lever and game (e.g., C_1). Unavailability of the lever press not chosen was signalled by the illumination of the red light on its manipulandum. Once the chosen instrumental response requirement had been completed, the appropriate power-switch/game combination became available, signalled by the illumination of its green light. The subject was allowed to play with the game for 60 sec before it became unavailable and a choice between the two lever presses was provided again. Each contingency session consisted of 15 one min cycles.

The second contingency session ensued 24-36 hrs later. The only change relative to the first contingency session was an increase in the instrumental requirements (3 or 6 sec) to gain access to the TV Bowling and Echo games. After a short two minute rest period, Contingency Session 2 was followed by a third, identical session with still another increase in the instrumental requirement (5 or 10 sec). Lacking no previous research to draw upon, the price shifts in the present experiment were based on data provided by several pilot subjects.

The response requirement for the low shift subjects, across contingency sessions, was set at 1 sec (Contingency Session 1), 3 sec (Contingency Session 2), and 5 sec (Contingency Session 3). The corresponding increases for the high shift were 1 sec, 6 sec, and 10 sec. Control subjects received only paired baseline sessions across all five phases. Table position of the games (left or right side) was counterbalanced across subjects. The microprinter recorded selection of the response alternatives for every one min cycle.

Results and Discussion

According to the conservation model (Allison, 1976), the total amount of some dimension apportioned to an instrumental and contingent response is conserved across schedule changes for individual subjects. Hence, if the k_i parameters, reflecting the conserved dimension, could be estimated, it should be possible to predict the number of choices made for a particular game (for any training session) by rearranging Equation (5) and inserting the known parameters. To test the accuracy of such predictions, it is necessary to compare the obtained and predicted choices for Game One (Mindbender) and Game Two (Echo or TV Bowling). If the conservation model is correct, and k_i does not vary widely across schedules, the predicted game choices of Equation (5) should have a high correlation relative to the obtained choices. Estimates of k_1 and k_2 were calculated by using Equation (5) to set the initial baseline values equal to Contingency Sessions 1 and 2 as follows:

Contingency 1 Baseline 1

$$N_1(I_1 + k_1C_1) + N_2(I_2 + k_2C_2) = O_i + k_1O_{c1} + k_2O_{c2}$$

Rearranging,

$$k_1(N_1C_1 - O_{c1}) + k_2(N_2C_2 - O_{c2}) = O_i - N_1I_1 - N_2I_2 \quad (9a)$$

Contingency 2 Baseline 1

$$N_3(I_3 + k_1C_3) + N_4(I_4 + k_2C_4) = O_i + k_1O_{c1} + k_2O_{c2}$$

Rearranging,

$$k_1(N_3C_3 - O_{c3}) + k_2(N_4C_4 - O_{c4}) = O_i - N_3I_3 - N_4I_4 \quad (9b)$$

Equations (9a) and (9b) were used to form simultaneous equations to derive unique $\underline{k}_1$ and $\underline{k}_2$ values. Since the obtained number of game choices for the initial baseline through the second contingency session (choices $\underline{N}_1, \ldots \underline{N}_4$) were used to estimate the $\underline{k}_i$ parameters, only the number of choices for the last contingency session ($\underline{N}_5$, Game Two choices, e.g., TV Bowling or Echo; $\underline{N}_6$, Game One choices, e.g., Mindbender) were independent of the data. Predictive equations for Contingency 3 were obtained by rearranging Equation (5) and inserting the $\underline{k}_i$ values to solve for $\underline{N}_5$ and $\underline{N}_6$.

The correlations between the obtained and predicted game choices for the third contingency session were, $\underline{N}_5$ ($r = 0.727$) and $\underline{N}_6$ ($r = 0.760$). Both correlations proved to be significant,

N_5, $z(31) = 3.98$, $p < .05$; N_6, $z(31) = 4.23$, $p < .05$. The proportion of variance for the predicted scores accounted for by the obtained scores was N_5 ($r^2 = 0.528$) and N_6 ($r^2 = 0.578$). The slope/intercept for both games were N_5, 0.80/1.44 and N_6, 0.94/0.02. The foregoing analyses provide some support for the premise that the subject conserves a dimension apportioned to the instrumental and contingent responses across sessions. Possible variation in the k_i parameters across schedules could account for the lack of higher correlations between obtained and predicted choices. It is possbile, of course, to obtain a significant linear correlation between the predicted and obtained scores without necessarily having accurate predictions. To exclude the possibility that the predicted scores are linearly related but differ from the obtained scores by a constant amount, additional analyses were performed.

If the predictions were totally accurate, the differences between the predicted (PR) and obtained (O) choices should be zero (e.g., $\bar{X}d=0$). The mean difference score for the Game Two (N_5) and Game One (N_6) choices were $Xd = 0.454$, $t(31) = 1.51$, $p > .05$, and $\bar{X}d = -0.224$, $t(31) = -0.84$, $p > .05$, respectively. These analyses indicate that the mean difference score did not significantly differ from zero.

The k_i parameters used in the calculations to predict both sets of game choices were estimated on an individual basis. The mean k_1 and k_2 values for each experimental condition are presented in Table 1. In addition, the mean for predicted and obtained choices for both N_5 and N_6, across experimental groups, are presented in Table 2.

INSERT TABLES 1 AND 2 ABOUT HERE

Turning now to the economic issues, it was predicted that the groups receiving the substitutable pair of games should demonstrate more elasticity of demand (e.g., greater % change in contingent responding relative to % change in the instrumental requirement) than the nonsubstitutable group. Specifically, the substitutable group should choose to play with _Mindbender_ more often than _Echo_ as the latter game's price increases compared to subjects in the nonsubstitutable condition experiencing an identical price increase for _TV Bowling_. In addition, differences between high and low price shifts were examined by comparing performances across changes in reinforcement schedules.

To examine the amount of time spent on Game Two as a direct function of price, own-price elasticity measures were calculated for each subject in the experimental conditions (see Equation 7). The elasticity measure affords an index of the _rate of change_ in responding across sessions for each subject rather than relying on absolute differences to detect group differences. Subjects in the control conditions were not required to perform the instrumental response for access to either game; consequently, their data were omitted from this conversion to elasticity scores due to the obvious absence of a price requirement.

A 2 (game pair: substitutable or nonsubstitutable) X 2 (price shift: high or low) X 3 (sessions: Baseline 1 to Contingency 1, Contingency 1 to Contingency 2, and Contingency 2 to Contingency 3) ANOVA was employed to examine the computed elasticity scores. No factors were significant (all p's > .10). The mean elasticity scores, collapsed across groups, per session were -0.23 (Baseline 1 to Contingency 1), -0.02 (Contingency 1 to Contingency 2), and 0.54 (Contingency 2 to Contingency 3), indicating that the percentage decrease in responding for Game Two (*Echo* or *TV Bowling*) was less than the percentage increase in the bar press requirement (price) across sessions (inelastic demand). This finding does not support the predicted performance differences between groups receiving the nonsubstitutable and subsitutable games or any differences as a result of high and low price shifts.

Corresponding to the own-price elasticity measures on Game Two, cross-price elasticity scores (see Equation 8) were calculated for individual response times on Game One (*Mindbender*) to determine their change as a function of increases in price on Game Two. The ANOVA for the Game One cross-price elasticity measures revealed no significant effects (all p's > .10). This indicates that the cross-price elasticity measures for Game One and did not differ for substitutable and nonsubstitutable games or high/low price shifts.

Although the elasticity measure acts to reduce subject variablity by comparing rates of change rather than absolute differences between subjects' performances, another difficulty with experiments involving schedule changes may not be as easily circumvented. It is difficult to attribute the decline in the amount of responding for Game Two, *Echo* or *TV Bowling*, to price increases alone, due to the simultaneous reduction available in playing time as a consequence of the increased amount of time spent bar pressing. The different amounts of time available to engage in Game Two responding, as a function of different price shifts, may exaggerate any *real* decrement caused by these price changes. To circumvent this possible confound, individual performances were analyzed based on the number of times Game Two (*Echo* or *TV Bowling*) was selected relative to the total number of Game One and Two selections per session (e.g., $N_1/N_1 + N_2$, $N_3/N_3 + N_4$, and $N_5/N_5 + N_6$). In effect, this transformation places choices within each session on a relative scale, allowing comparisons with the control groups. These calculations for the control groups could present a further problem in that baseline sessions allowed responding to both games within each one minute interval. Close inspection of the data, however, revealed that subjects responded to either one game or the other on an almost exclusive basis for each one minute baseline interval.

It is assumed that the predicted differences between substitutable and nonsubstitutable conditions and differences between groups receiving high and low price shifts should hold for the selection proportion measures. Figure 1 shows the number of choices for Game Two relative to the total number of both game choices for each session. Although there appears to be a predicted decline in choices across Sessions 2-3 for the experimental groups, SL, NL, SH, and NH, the high shift groups show an unexpected increase in Game Two choices for the last contingency period (Session 4) despite another increase in price. The control group NC shows a vacillation in Game Two choices across sessions as might be expected if subjects were merely alternating between Game One and Game Two. Group SC demonstrated a slight decreasing trend in Game Two responding across Sessions 2-4. This is unexpected since Group SC was not subject to price constraints.

INSERT FIGURE 1 ABOUT HERE

A 2 (game pair) X 3 (price shift) X 5 (session) ANOVA performed on Game Two responses seen in Figure 1 indicated only a marginally significant Group X Session interaction, $F(20, 168) = 1.57$, $p < .07$. All other effects were nonsignificant (all p's < .30). This single trend toward significance coupled with the lack of consistent performance differences between substitutable/nonsubstitutable and high/low shift conditions in Figure 1, does not support the predicted differences based on the substitutability of the game pair or high/low price increments. Corresponding results for Game One selection proportions were not analyzed in that these data are exact complements of the Game Two proportions and would not have yielded any additional information.

Own-price elasticity measures were also analyzed for the selection proportions adjusted for income effects. The results of a 2 (game pair) X 2 (price shift) X 3 (session) ANOVA revealed only a significant main effect for the change in elasticity across sessions, $F(2,22) = 5.02$, $p < .01$. The change across sessions, Baseline 1-Contingency 1, Contingency 1-2, and Contingency 2-3, was inelastic with mean elasticity measures of 0.02, -0.01, and 0.29, respectively. A Tukey post-hoc comparison test showed the elasticity mean of 0.29 to be significantly different from the other two means (both p's $< .05$). The first two means did not differ from each other ($p > .10$). This finding reflects an inelastic demand, indicating that, collapsed across the type of game pair and magnitude of price change variables, the percentage of decrease in Game Two responding across sessions is less than the corresponding percentage increase of the instrumental requirement. The significant difference among the mean elasticity measures across sessions also indicates that the elasticity of demand does not remain constant but becomes more elastic as price increases.

The results describing the economic variables in the foregoing analyses portray somewhat of an unclear picture. The classification of substitutes and nonsubstitutes appears to be ineffective in the context of the foregoing experiment. This is further corroborated by the subjects' self-report scales, indicating how similar they judged the two games. Subjects judged both game sets along the 5 point continuum as having more dissimilar than similar characteristics (X substitute = 3.5; X nonsubstitute = 4.0; $t(46) = 1.85$, $p > .05$). This may explain the highly inelastic demand for Game Two, in that the games were interpreted as dissimilar regardless of their designated level of substitutability; hence, Game One may not have been substitutable enough to promote elastic responding. This suggests that increasing the similarity of a game pair may promote greater performance distinctions for the substitutability manipulation.

The results of the high/low price shift were also equivocal. Although the elasticity analysis performed on the selection proportions give some credence to the effectiveness of the price manipulation, comparisons between experimental and control groups make such a conclusion less clear. It is feasible that larger increments in cost were needed to make the difference in price shifts more discernible.

Experiment 2 involves a test of the foregoing hypotheses. Specifically, it is predicted that an increase in the similarity of the substitutable game pair will promote more elastic responding for Game Two relative to subjects receiving a nonsubstitutable game pair. In addition, larger price increments relative to Experiment 1 should act to create greater elasticity of demand for Game Two relative to a control group. These hypotheses will, again, be tested within the context of the conservation model.

Experiment 2

Method

Subjects. Thirty-two subjects enrolled in an Introductory Psychology course participated in order to fulfill partial requirements for a course.

Apparatus. The same general apparatus employed in Experiment 1 was used here. Modifications involved a change in games. The substitute pair consisted of *Merlin Blackjack* and *TV Blackjack* played on the same units described in Experiment 1. The *Merlin Blackjack* game differed from the similar TV game in that the subject was not to exceed 13 cumulative points per game rather than the usual 21. The nonsubstitute pair consisted of *Merlin Blackjack* and *TV Bowling*.

Design. The present design was similar to Experiment 1 with changes only for price shifts. In this experiment, only a single succession of price shifts occurred for each experimental subject, e.g., a 2 (game pair: substitutes or nonsubstitutes) X 2 (price shift: experimental or control) X 5 (sessions: Baseline 1, Contingencies 1-3, and Baseline 2) design.

Procedure. The same general procedure was followed in the second experiment relative to Experiment 1; only the price shift for Game Two was changed for the experimental groups. The new instrumental response requirement was set at 1 sec for Contingency 1, 10 sec for Contingency 2, and 20 sec for Contingency 3. The instrumental response requirement for Game One was fixed at 1 sec across all contingency periods. Completion of the instrumental requirement enabled the subject to engage in 1 min of playing time for the respective games. Subjects in the control groups received free baseline sessions across all training phases. Finally, the same questionnaire gauging subjects' perceived game similarity given in Experiment 1 was repeated upon the conclusion of Experiment 2.

Results and Discussion

The conservation model hypothesizes that a subject will conserve some unspecified dimension apportioned to an instrumental and contingent response, and that this weighted sum of activities will be constant across schedules. If this relation is true, the k_i parameters in Equation (5) should remain relatively stable across training sessions in the present experiment. Hence, it should be possible to predict the dependent variable (Game choices: N_1. . .N_6) by rearranging Equation (5) and substituting in the known parameters. In order to test these predictions, it was necessary to calculate k_1 and k_2 values for each subject (see Equations 9a and 9b) as previously described in Experiment 1. These parameters were then used in conjunction with Equation (5) to predict the number of choices made for both games (e.g., N_5, Game Two choices--TV Bowling or TV Blackjack; and N_6, Game One choices--Merlin Blackjack) during the last contingency session for the experimental groups. If the dimension was indeed conserved, then the correlations between the predicted and obtained game choices should be high. The mean k_1 and k_2 values for both experimental groups is reported in Table 3.

INSERT TABLE 3 ABOUT HERE

In light of the smaller sample size relative to Experiment 1, t-tests were used to examine the relationship between the predicted and obtained game choices (Bruning & Kintz, 1968). The correlation between the predicted and obtained choices for Games Two and One during the last contingency session were N_5 (r = 0.260) and N_6 (r = 0.687), respectively. A close inspection of the data revealed that the low correlation between predicted and obtained choices for both games was due substantially to the performance of the nonsubstitutable group. The correlation between the predicted and obtained choices for both games were also computed for the substitute, N_5 (r = 0.910) and N_6 (r = 0.845), and nonsubstitute, N_5 (r = -0.03) and N_6 (r = 0.196), conditions, separately. The mean number of obtained and predicted choices for both experimental groups are shown in Table 4.

INSERT TABLE 4 ABOUT HERE

The correlations for the substitute groups were significant, N_5, $t(6) = 8.21$, $p < .01$ and N_6, $t(6) = 5.91$, $p < .01$. The amount of variance in the predicted scores accounted for by the obtained scores in the substitute condition was, N_5 ($r^2 = 0.828$) and N_6 ($r^2 = 0.714$). The slope/intercept for the predicted and obtained scores were, N_5, .789/2.13 and N_6, .793/.926. The corresponding analyses for the nonsubstitute condition were not performed due to the obvious lack of relationship between the predicted and obtained scores.

As in Experiment 1, the difference scores between the predicted and obtained choices were compared to the obtained choices alone for the substitute condition (e.g., PR-Q vs. Q). If the predicted choices were entirely accurate the mean for the difference scores for both games should be zero (e.g., $\bar{X}d = 0$). The mean difference score for Game Two ($\bar{X}d = 0.945$) did not significantly differ from zero, N_5, $t(7) = 1.86$, $p > .05$. The mean difference score for Game One ($\bar{X}d = 1.33$), however, did significantly differ from zero, N_6, $t(7) = 3.44$, $p < .05$. This latter finding suggests that, despite the previously reported significant linear relationship between predicted and obtained choices, the scores do differ by some constant amount.

The lack of correspondence between the obtained and predicted choices for the nonsubstitutable condition is particularly noteworthy. It may be that under the more stringent price constraints of Experiment 2, relative to Experiment 1, the nature of the game pair becomes more important in its effects on the conserved dimension, k_i. The explanation of this effect remains unclear, however, except to suggest that the unit-free dimension apportioned to the instrumental and contingent response may not be conserved (e.g., k_i parameter may be less stable) with nonsubstitutable response pairs compared to substitutable ones under high prices. The apparent superiority of the model to deal with substitutable alternatives must be interpreted cautiously in light of the finding that the mean of the Game One difference scores (e.g., PR-O) significantly differs from zero, indicating that, although the predicted and obtained scores are linearly related, there is not a one to one correspondence.

Focusing upon the economic variables, it was predicted that the subjects receiving the more substitutable game pair would show less responding to Game Two, relative to the subjects receiving the nonsubstitutable pair. In order to test this prediction and examine any changes in elasticity (e.g., % change in Game choices relative to the % change in price) across contingency sessions, the data from the present experiment were subjected to the same analyses as in Experiment 1. Own-price elasticity measures were calulated for each subject based on the time spent on Game Two, _TV Bowling_ or _TV Blackjack_. A 2 (game pair) X 4 (session) ANOVA performed on these measures revealed no significant effects (all p's > .30). The mean scores across sessions, however, indicated a more elastic demand than in Experiment 1. The mean elasticity scores collapsed across the game condition were 0.10 (Baseline 1-Contingency 1), 0.08 (Contingency 1-2), 0.05 (Contingency 2-3), and 0.68 (Contingency 3-4). The corresponding cross-price elasticity measures for Game One, _Merlin Blackjack_, were subjected to an identical ANOVA with no effects achieving significance (all p's > .10).

To counteract any possible confound due to less playing time as a result of increased time spent bar pressing as discussed in Experiment 1, the number of Game Two choices were examined in relation to the total number of choices made for both Game One and Two per session. This proportion measure was calculated for all groups across sessions, Baseline 1 to Baseline 2. It was predicted that subjects in the substitutable condition would make fewer Game Two choices across price increments compared to subjects in the nonsubstitutable condition, and the experimental groups would show a decrease in responding relative to control groups.

The Game Two proportion of choices are depicted in Figure 2. Both nonsubstitute and substitute experimental groups, N and S, evidence a sharp decrease in Game Two choices between Session 2 (Contingency 1) and Session 3 (Contingency 2). The substitute group, however, did make fewer Game Two selections than the nonsubstitute group during Session 4 (Contingency 3), as predicted, despite a further increment in price. The decline in the proportion of Game Two choices for the control group NC at Session 4 was unexpected and makes any distinction between the substitute and nonsubstitute experimental groups equivocal. Despite the apparent group differences in the proportion of choices, a 2 (game pair) X 5 (session) ANOVA revealed no significant effects for Game Two selections (all p's $> .25$). Due to the nature of the present proportion measure, Game One proportions would yield the _exact_ complement of Game Two proportions and therefore remained unanalyzed.

INSERT FIGURE 2 ABOUT HERE

Own-price elasticity measures were also computed for the Game Two selection proportions across sessions. More elastic responding was predicted for the substitute condition relative to the nonsubstitute condition. A 2 (game pair) X 4 (session) ANOVA performed on the elasticity data revealed no significant effects (all $\underline{p}$'s > .10). Consistent with the findings from Experiment 1, the Game Two proportions showed inelastic responding across sessions. The mean elasticity measures, collapsed across groups, were 0.01 (Baseline 1 to Contingency 1), 0.04 (Contingency 1 to Contingency 2), and 0.01 (Contingency 2 to Contingency 3). No diferences between the substitute and nonsubstitute conditions can be confirmed from this analysis.

The post-experimental questionnaire indicated that subjects across conditions differed only moderately in their estimation of the games' degree of similarity/dissimilarity (X, substitute = 2.92; X, nonsubstitute = 3.30, $\underline{t}(30) = 1.05$, $\underline{p} > .05$). As in Experiment 1, the lack of a greater perceived difference between game conditions may account for the lack of a clear statistical separation between substitute and nonsubstitute conditions. This methodological problem and the lack of effective price constraints will be discussed later in detail.

Discussion

The basic premise of the conservation model is that the weighted sum of activities in a situation is constant across schedule contraints (Staddon, 1979a). This premise is given some support by the correlation analyses for experimental groups in Experiment 1 and the experimental group receiving the substitute condition in Experiment 2. The correlation between predicted and obtained choices in both instances was significant.

The lack of even higher correlations in Experiment 1 between the obtained and predicted choices for both games suggest that the conserved dimension between the instrumental and contingent responses, may change across schedules of reinforcement. The severe breakdown in correlations between the predicted and obtained values for game choices in Experiment 2 may be even more damaging to the conservation assumption of stable $\underline{k}_i$ parameters. It will be recalled that the correlation for the predicted and obtained game choices was particularly low for the nonsubstitute groups when compared to subjects receiving the substitutable pair of games. The conservation model does not account for any differences in predictions based on the degree of substitutability of concurrent choices, although such a modification of the conservation model would be possible. To be sure, any distinction made on the basis of the game pair's substitutability is even more equivocal in light of the linear, yet inaccurate predictions for Game One substitute choices in Experiment 2.

It could be argued that certain implicit procedural assumptions of the conservation model were violated, thus accounting for the lack of stronger correlations in both experiments. The typical conservation procedure requires the subject's responding to conform to some preestablished criteria during a particular training session before being transferred to the next session (see Shapiro & Allison, 1978). The lack of any explicit "stability criteria" in the present experiments could be viewed as an omission of an important procedural ingredient. Pilot data, however, indicated that subjects consistently alternated between games during baseline conditions. Hence, it was assumed that a baseline of long duration would not result in a bias for one game over the other. Consequently,the present baseline was considered suitable to establish the subjects' characteristic responding.

It could also be argued that the $\underline{k}_i$ parameter calculations in both experiments differ from the usual method of derivation (see Shapiro & Allison, 1978) possibly accounting for any low correlations between predicted and obtained choices. The very premise of the conservation model would seem to offset this argument in that the dimension which these very parameters represent is supposed to remain relatively stable across such sessions; hence, the present equations should be consistent with the conservation model's assumptions. A possible explanation for the low correlations for the nonsubstitutable group choices in Experiment 2 is that the higher price changes interacted with the nature of the game pair. That is, in Experiment 1 when the price changes were less severe, the conserved dimension remained somewhat stable across sessions, making for high correlations between obtained and predicted choices. Under the more stringent

Experiment 2 price changes, however, the conserved dimension may be subject to greater change when choices are nonsubstitutable, thus accounting for the low correlations. In essence, the generality of the conservation model in dealing with diverse contingent responses, especially across stringent schedule constraints, is in need of further examination.

Leaving the discussion of the present results for the moment, it may be of value to consider the conservation model in juxtaposition to other approaches of a similar nature. The conservation model belongs to a general class of theories that have been categorized as of the equilibrium type (Staddon, 1979b). In operant equilibrium theories, behavior is explained by reference to a set of conditions that it must satisfy. For example, conservation theory states that subjects behave as to conserve a quantity which is a linear combination of the rates of performance of the instrumental and consummatory responses (Lea, in press). This can be contrasted to the more mechanistic approaches in which behavior is explained in terms of antecedent causal relations (e.g., Hull, 1943; Spence, 1960; Killeen, 1975).

Akin to the conservation theory are a subclass of equilibrium theories known as optimality analyses (see Staddon, 1979b). Optimality analyses assume that an organism attempts to maximize some variable while operating under various constraints. Staddon, for example, has suggested that this maximized variable might take the form of net energy intake as in optimal foraging studies (e.g., Krebs, 1973).

Staddon has presented such an optimality-type theory that could serve as an alternative to the conservation model. Staddon assumes that the functional relations between the equilibrium levels of an instrumental and contingent response, under different schedules, conform to an homeostatic rule. This rule asserts that organisms act to minimize the model between their distribution of responses occurring in a "free" situation compared to the same activities under schedule conditions. This approach seems to handle the conservation data, and at the same time predicts performances that are disparate to the conservation models predictions (Mazur, 1975).

Lea (in press) has discussed a general theory that incorporates aspects of both the conservation model and the approach suggested by Staddon. Lea criticizes conservation theory's implication that the subject will be equally satisfied with a condition so long as the value that is conserved, _k_, is maintained. Lea postulates a _utility variable_ (_u_) to replace _k_ in the conservation model. According to Lea, the variable _u_ assesses the subject's "satisfication." Like Staddon, Lea assumes that the paired baseline condition represents some sort of ideal, and the nearer the subject is to it, the higher the satisfication.

A major difference between the conservation model and the one proposed by Lea is that conservation specifically allows for the fact that the instrumental response and both consummatory responses substitute for one another in some sense under a concurrent-schedule. Lea's model, on the other hand, treats these responses as independent contributors to utility. In light of the conservation model's present difficulty in dealing with the nonsubstitutable alternatives relative to the substitutable ones in Experiment 2, the alternative mdoel proposed by Lea may in fact, be better equipped to explain the present data in that the value conserved does not appear to be invariant across schedules as the conservation model supposes. Lea (personal communication) has proposed a test of this very assumption by examining the conservation theory across several different schedules' combinations. If the _k_ parameters of the model are always the same or vary only randomly about the mean, then the conservation model's assertion of relatively stable _k_'s is correct, but if they vary systematically with schedule constraints, then the model is wrong.

In addition to possible variations in the conserved dimension across schedules, there are other difficulties in using the conservation model in the present instance. The present experiments attempt to extend a model developed from data generated from infrahuman subjects. The control of extraexperimental sources of reinforcement may be critical for the success of the conservation model to more efficiently prevent satiation of the experimental sources. On this account, extrapolating the model to human behavior is, of course, a problem and satiation and fatigue factors need to be adequately controlled. The present experiment was conducted over two separate training sessions for each subject in an attempt to attenuate such factors, however, the responding of the control subjects would suggest a need for sessions of shorter durations extended over a longer period of time. Another difficulty in applying the conservation model to human choice-behavior concerns the nature of the response alternatives. The conservation model has dealt only with the relationship between essential commodities (e.g., food, water). There is some data to indicate that the predictions of the conservation model are at odds with studies dealing with non-essential commodities (Kagel, personal communication). Whether this model is adequate to deal with choices between non-essential responses as in the present experiment will require further investigation.

Turning now to the economic issues, the present studies demonstrate a need for methodological refinements in dealing with the issue of substitutability. The present study relied on an intuitive classification scheme to establish substitutable and nonsubstitutable repsonses. The absence of any consistent differential effect for the type of responses, substitutable and nonsubstitutable, in any of the performance measures would argue against repeating such a procedure. This isolated deficiency is suggestive of a more general problem in dealing with the substitutablity issue.

It appears that at present there is no proven way of specifying the substitutabiilty of responses on an a priori basis. Despite the successful use of this variable in some operant experiments, the proof of the effectiveness of the classification scheme specifying substitutability on an intuitive basis can only be judged in a post-hoc fashion (e.g., Rachlin et al., 1976). That is, the validity of the method of classification can only be ascertained by differential effects in the data that has already been accumulated. This problem is closely related to the circularity issue of reinforcement discussed previously.

Rachlin et al. (1976) have suggested a refinement to the intutive approach of the substitutability issue. By using Tverskey's (1972) elimination-by-aspects theory, these authors suggest that substitutability might be treated in terms of the ratio of common and unique aspects between choices. An alternate solution has been offered by Allison et al. (1979). These authors suggest that the dimensional parameter k_i in the conservation model could be viewed as a kind of substitutability constant. Illustratively, perfect (unit) substitutability would be exemplified when *k* = 1, meaning that *x* units of response *i* are substitutable for *x* units of response *c*. Allison et al. also elaborate as to how this technique can be used to predict the numerical value of *k* for two responses which have not yet been paired in a contingency schedule.

Despite the sophisticated discussion that the substitutability variable has achieved in the psychological literature (e.g., Allison, et al., 1979; Rachlin & Burkhart, 1979; Rachlin et al., 1976) it is an issue inherent with many obstacles. The substitutability issue, as treated to date, rests upon the law of transitivity holding for response or commodity pairs. That is, if two commodities were substitutable for a third commodity, then they should be substitutable for each other according to traditional economic thought. There is some evidence that choices are not always transitive for infrahuman subjects (Navarick & Fantino, 1974), and nonconformance to such expectations by humans is well documented in the economic literature as well (see Rachlin et al., 1976). Moreover, substitutability as a property, in and of itself, is not symmetric. For example cars will run on alcohol and in a case of extreme urgency Scotch whiskey could be used as a substitute for gasoline; however, guests at a cocktail party might violently object to the reverse situation (Lea, personal communication).

The most fruitful solution to the substitutability issue in operant models may be to ignore it altogether. For instance, Lea's (in press) model has no parameters representing substitutability, yet it is sensitive to the extent to which two reinforcers contribute to characteristics of the model such as utility. Hence, although there is no one term in the model deserving of the title "substitutability", it does account for the effect that different types of reinforcers have on responding.

Although the issue of substitutability appears to be an economic issue that is not easily translated into psychological terms, other economic variables may prove to be more easily grasped. The recent surge of interest in econometrics by various psychologists (e.g., Allison, 1979; Lea, 1978; Rachlin & Burkhart, 1978; Rachlin et al., 1976) has not been intended to determine how the economy works, but to suggest how choice-behavior may be viewed from an economic framework. After all, a consumer choosing between two commodities at certain prices bears strong similarities to a subject in an operant experiment responding to two schedules leading to different reinforcers. The finding of both experiments appear to indicate such a consumer-like situation. There appears to be a general decline in responding to Game Two as a function of increments in the instrumental response requirement (price) supported by the selection proportion measures from both experiments. However, occasional fluctuations in performance on the part of the control groups tends to obfuscate this conclusion.

The elasticity analyses in the present experiments indicated inelastic responding. To induce elastic responding in dealing with nonessential items it may be necesary to make a number of methodological changes in future studies. It may be that subject's in the present study could not discern the changes in price as they occurred across sessions and still more stringent prices should be used. A more likely explanation for the highly inelastic demand is that the present instrumental response requirement may not translate easily as a price analogue. For a price analogue to be effective, subjects must value their available purchasing resources. Although the present experiment used time as a resource, subjects may have lacked the necessary feedback to render this commodity its appropriate value. Without some kind of external referent such as a timer to index the amount of resources being "spent", the functional resouce may have been the effort to bar press alone. Bar pressing may be a resource that is too easily replenished, rendering it ineffective as a resource to be valued and thriftly spent. The most effective experimental price analogue may be to use tokens as payment for work performed, which could then be exchanged for a variety of responses or commodities.

The more recent use of economic demand theory as a model for certain aspects of operant choice-behavior does appear promising in light of the growing body of research demonstrating its profit as a heuristic tool (e.g., Allison, 1979; Lea & Roper, 1977; Lea, 1978, in press; Rachlin & Burkhart, 1979; Rachlin et al., 1976). Relatedly, studies of a more social nature have used operant methods to detail the conditions of cooperation which could also easily lend itself to an economic analysis (e.g., Hake, Olvera, & Bell, 1975). Future work in developing economic analogies and social behavior might include such areas as bargaining, gambling, and coalition formation.

In using economic issues as analogues to psychological behavior, it should be understood that economic demand theory is not a theory in at least one sense. The demand curve for single commodity may have practically any shape and still be consistent with the theory (Lea, 1978). Demand theory, however, does provide a framework within which particular theories can be developed for particular purposes. Conservation theory and other equilibriun theories may be of this general type. Demand theory may provide a mold in which these theories can be cast to study choice in a consistent manner. The reverse should also hold true. Theories discussed in the present article can serve as a basis for many econometric investigations that would provide laboratory support for many issues of long historical contention.

Reference Notes

1. Mellgren, R. L. Theories and acquisition in appetitive situations. Unpublished manuscript. Department of Psychology, University of Oklahoma.

References

Allison, J. Constrast, induction, facilitation, suppression, and conservation. *Journal of the Experimental Analysis of Behavior*, 1976, *25*, 185-198.

Allison, J. Demand economics and experimental psychology. *Behavioral Science*, 1979, *24*, 403-415.

Allison, J., Miller, M., & Wonzy, M. Conservation in behavior. *Journal of Experimental Psychology: General*, 1979, *108*, 4-34.

Battalio, R. C., Kagel, J. H., Winkler, R. C., Fisher, E. C., Jr., Basmann, R. L., & Krasner, L. A test of consumer demand theory using observations of individual consumer purchases. *Western Economic Journal*, 1973, *11*, 411-428.

Baumol, W. J. Economic theory and operations analysis. Englewood Cliffs, New Jersey: Prentice Hall, 1972.

Bolles, R. C. *Theory of motivation*. New York: Harper & Row, 1976.

Butler, R. A. The effect of deprivation of visual incentives on visual exploration motivation in monkeys. Journal of Compartive and Physiological Psychology, 1957, 50, 177-179.

Breland, K., & Breland, M. Animal behavior. New York: The Macmillan Company, 1966.

Bruning, J. L., & Kintz, B. L. Computational handbook of statsitics. Glenview, Ill.: Scott Foresman and Company, 1968.

Castro, B., & Weingarten, K. Toward experimental economics. Journal of Political Economy, 1970, 78, 598-607.

Hake, D. T., Olvera, D., & Bell, J. C. Switching from competition to sharing or cooperation at large requirements: Competition requires more responding. Journal of the Experimental Analysis of Behavior, 1972, 18, 333-343.

Hogan, J. A., Kliest, S., & Hutchings, C. S. L. display and food as reinforcers in the Siamese fighting fish (Betta splendens). Journal of Comparative and Physiological Psychology, 1970, 70, 351-357.

Hull, C. L. Principles of behavior. New York: Appleton-Century, 1943.

Hull, C. L. A behaviour system. New Haven: Yale University Press, 1952.

Kagel, J. H., Battalio, R. C., Rachlin, H., Green, L., Bassman, R. L., & Klemm, W. R. Experimental studies of consumer demand behavior using laboratory animals. *Economic Inquiry*, 1975, *13*, 22-38.

Killeen, P. On the temporal control of behavior. *Psychological Review*, 1975, *82*, 89-115.

Lea, S. E. G. Psychology and the economics of demand. *Psychologcial Bulletin*, 1978, *85*, 441-466.

Lea, S. E. G. Concurrent fixed-ratio schedules for different reinforcers: A general theory. In C. W. Bradshaw (Ed.), *Recent developments in the quantification of steady-state behaviour.* Amsterdam: Elsevier/North Holland, in press.

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

MacKintosh, N. J. *The psychology of animal learning*. New York: Academic Press, 1974.

Meehl, P. E. On the circularity of the law of effect. *Psychological Bulletin*, 1950, *47*, 52-75.

Miller, N. E. Some reflections on the law of effect produce a new alternative to drive reduction. In M. R. Jones (Ed.), *Nebraska Symposium on Motivation: 1963*. Lincoln: University of Nebraska Press, 1963.

Olds, J., & Milner, P. Positive reinforcement produced by electrical stimulation of septal area and other regions of the rat brain. _Journal of Comparative and Physiological Psychology_, 1954, _47_, 419-427.

Premack, D. Reinforcement theory. In D. Levine (Ed.), _Nebraska Symposium on Motivation: 1965_. Lincoln: University of Nebraska Press, 1965.

Premack, D. Catching up with common sense or two sides of a generalization: Reinforcement and punishment. In R. Glasser (Ed.), _The nature of reinforcement_. New York: Academic Press, 1971.

Rachlin, H. _Behavior and learning_. San Francisco: W. H. Freeman, and Co., 1976.

Rachlin, H., & Burkhard, B. The temporal triangle: Response substitution in instrumental conditioning. _Psychological Review_, 1978, _85_, 22-47.

Rachlin, H., Green, L., Kagel, J. H., & Battalio, R. C. Economic demand theory and psychological studies of choice. In G. Bower (Ed.), _The psychology of learning and motivation_ (vol. 10). New York: Academic Press, 1976.

Samuelson, P. A. _Economics_. New York: McGraw-Hill Co., 1978.

Shapiro, N., & Allison, J. Conservation, choice, and the concurrent fixed ratio schedule. Journal of the Experimental Analysis of Behavior, 1978, 29, 211-223.

Sheffield, F. D., & Roby, T. B. Reward value of a non-nutrititve sweet taste. Journal of Comparative and Physiological Psychology, 1950, 43, 471-481.

Sheffield, F. D., Wulff, J. J., & Backer, R. Reward value of copulation without sex drive reduction. Journal of Comparative and Physiological Psychology, 1951, 44, 3-8.

Shettleworth, S. J. Constraints on learning. In D. S. Lehrman, R. A. Hinde, & E. Shaw (Eds.), Advances in the study of behavior, vol. 4. New York: Academic Press, 1972, 1-68.

Shettleworth, S. J. Reinforcement and the organization of behavior in golden hamsters: Hunger, enviornment, and food reinforcement. Journal of Experimental Psychology, 1975, 1, 56-87.

Spence, K. W. Behavior theory and learning. Englewood Cliffs, N. J.: Prentice Hall, 1960.

Staddon, J. E. R. Regulation and time allocation: A commentary on "Conservation in behavior." Journal of Experimental Psychology: General, 1979a, 108, 35-40.

Staddon, J. E. R. Operant behavior as adaptation to constraint. Journal of Experimental Psychology: General, 1979b, 108, 48-67.

Thorndike, E. L. *Animal intelligence*. New York: Macmillian, 1911.

Timberlake, W., & Allison, J. Response deprivation: An empirical approach to instrumental performance. *Psychological Review*, 1974, *81*, 146-164.

TABLE 1

	NL	SL	NH	SH
k_1	-0.11	0.54	0.92	0.61
k_2	-0.04	-0.10	0.13	1.06

Group means for k_1 and k_2 values per experimental condition.

TABLE 2

		NL	SL	NH	SH
N_5	predicted	7.54	5.71	6.92	8.08
	obtained	6.00	6.57	7.00	7.80
N_6	predicted	5.01	5.73	6.31	3.29
	obtained	6.14	5.57	5.50	4.14

Group means for predicted and obtained choices for _Echo/TV Bowling_ (N_6) and _Mindbender_ (N_5).

TABLE 3

	S	N
k_1	0.50	-0,12
k_2	0.36	0.34

Group means for k_1 and k_2 values per experimental condition.

TABLE 4

		S	N
N_5	predicted	6.57	7.38
	obtained	5.62	5.62
N_6	predicted	3.60	2.69
	obtained	3.37	4.25

Group means for predicted and obtained choices for TV Blackjack/TV Bowling and Merlin Blackjack (N_6).

Figure Caption

Figure 1. Proportion of Game Two (Echo or TV Bowling) choices across training sessions (Baseline 1, Contingencies 1-3, and Baseline 2) per group (SC = Substitute Control, NC = Nonsubstitute Control, SL = Substitute Low, NL = Nonsubstitute Low, SH = Substitute High, and NH = Nonsubstitute High).

Figure 2. Proportion of Game Two (TV Blackjack or TV Bowling) across training sessions (Baseline 1, Contingencies 1-3, and Baseline 2) per group (SC = Substitute Control, NC = Nonsubstitute Control, S = Substitute, and N = Nonsubstitute).

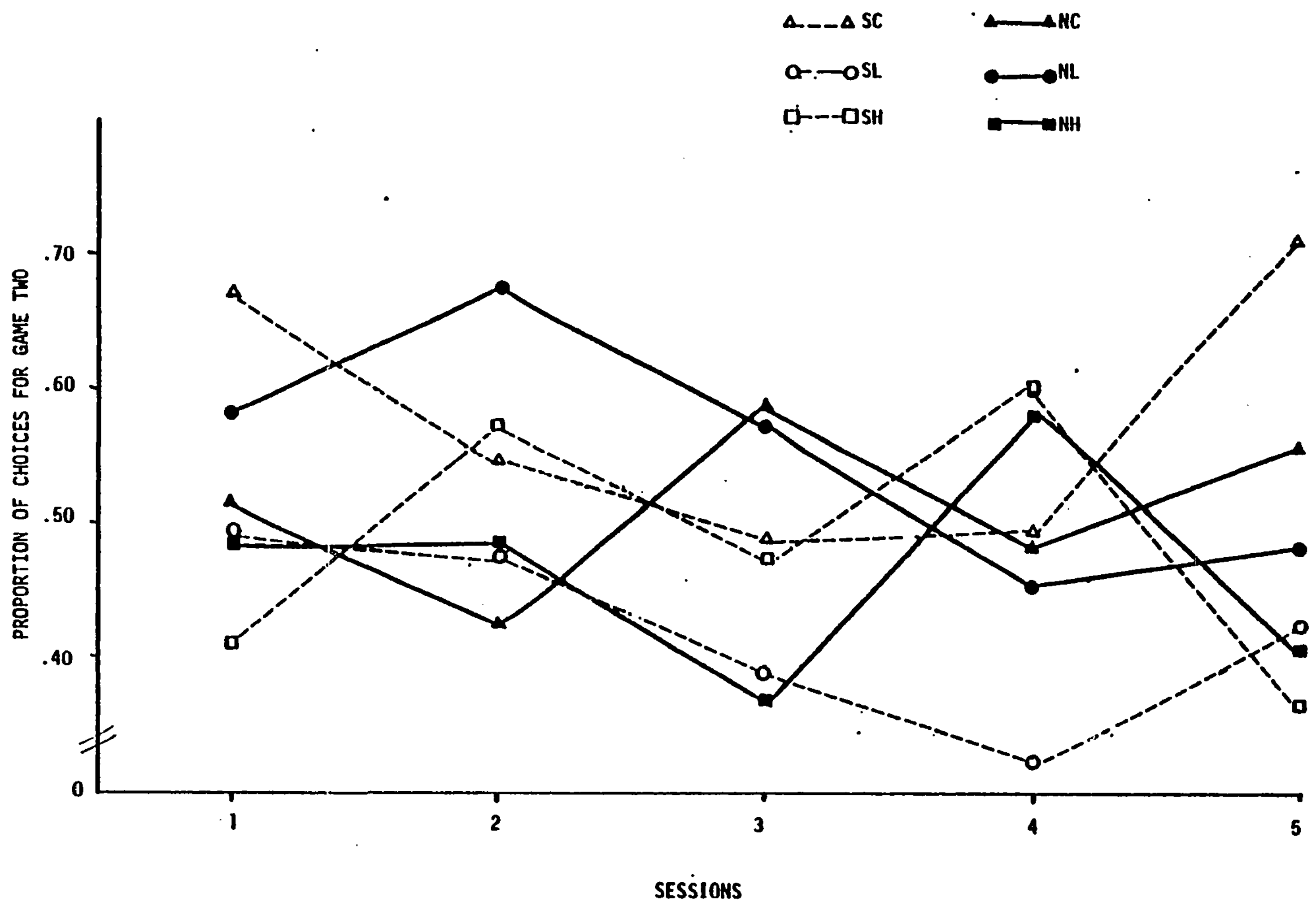
SC
NC
SL
NL
SH
NH
PROPORTION OF CHOICES FOR GAME TWO
.70
.60
.50
.40
0
1
2
3
4
5
SESSIONS

FIGURE 1

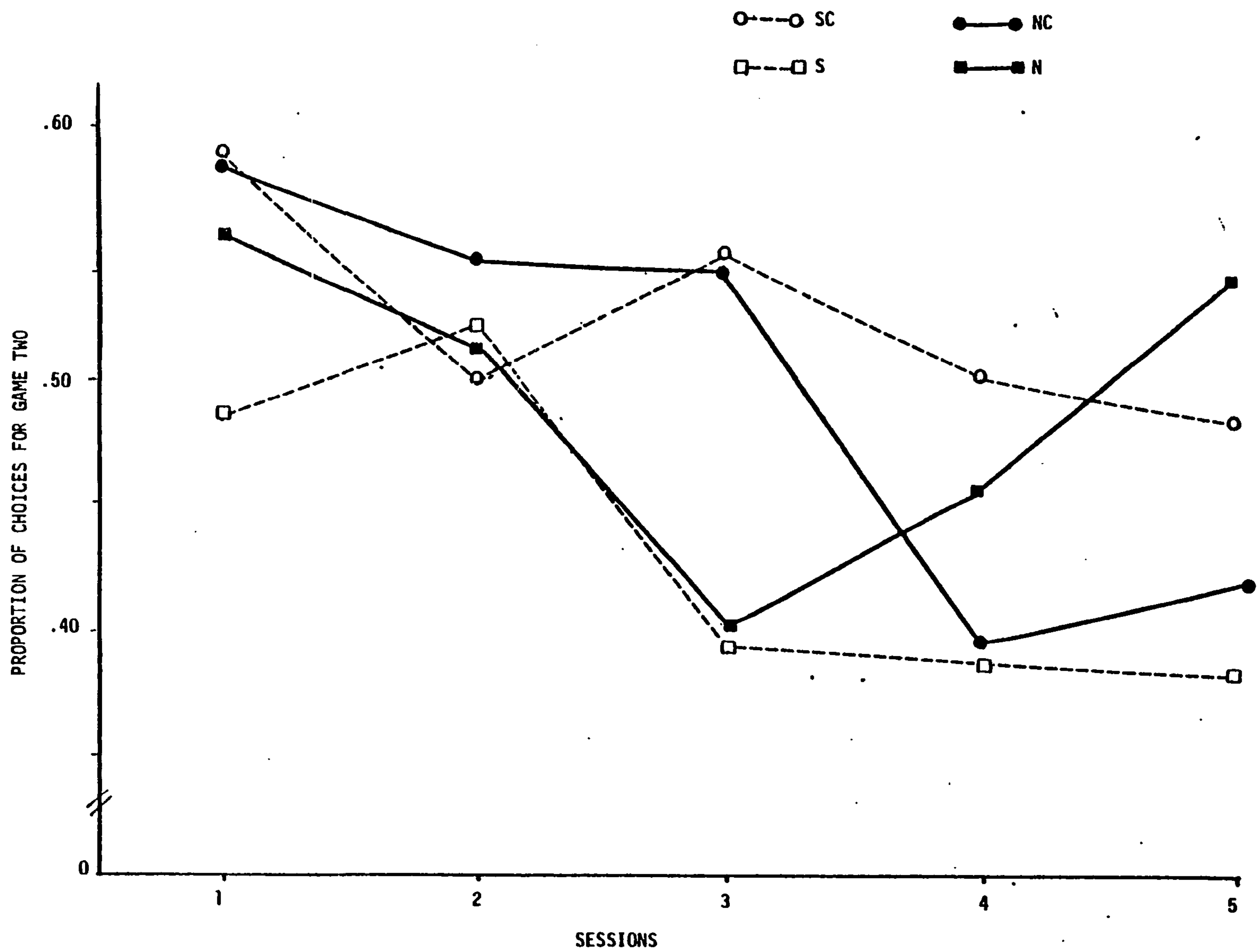
SC
NC
S
N
.60
.50
.40
0
PROPORTION OF CHOICES FOR GAME TWO
1
2
3
4
5
SESSIONS

FIGURE 2