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The Effects of Social Competition of the Economic Behavior of Rats

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ABSTRACT

Recent studies have shown that the law of supply and demand describes behavior on simple Variable Interval (VI) schedules. When the quantity of reinforcement supplied is large, animals will "pay" less for the reinforcer than when quantity supplied is small. These studies, however, feature organisms responding alone in operant chambers, without the social competition which economists argue drive the law of supply and demand. The present series of experiments examine the effects of social context on the economic behavior of rats on VI schedules. Rats responded on a pseudo-randomly assigned sequence of VI schedules differing in reinforcement rate. During half of the sessions, a second rat was placed in the chamber behind a Plexiglas barrier. As predicted by economic theory, there was an inverse relationship between the quantity of reinforcement supplied and the obtained behavioral cost of reinforcement. In addition, the presence of a "competitor" rat altered the relationship between supply and cost.

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INTRODUCTION

Beginning in the 1970's, several psychologists proposed that the behavior of animals in skinner boxes and other conditioning paradigms might follow the laws of economics (Allison, Miller, and Wozney, 1979; Lea, 1978; Rachlin, Green, Kagel, and Battalio, 1976; Staddon, 1979). In particular, an animal pressing a lever for food might be equivalent to a person providing labor or spending money in a standard market. That is to say that the models used to predict the behavior of humans might be interchangeable with models used to predict the behavior of animals in operant conditioning chambers. These hypotheses led to the birth of behavioral economics, a field in which theoretical economic principles are examined using laboratory methodology, yielding explanatory concepts and models for the behavior of organisms.

The field of behavioral economics has flourished in the last twenty years and both psychologists and economists have reaped the benefits of this union (Gilad, Kaish, and Loeb, 1984; Hattwick, 1989). Economists have gained access to an experimental laboratory in which to test and examine mainstream economic principles. Psychologists, in turn, profit by the opportunity to utilize an entirely new set of explanatory concepts and models for the study of behavior. The movement towards a more empirically oriented field of economics yields a richer, more accurate foundation from which to predict consumer behavior (Gilad, Kaish, and Loeb, 1984).

The analogy between economic theory and behavioral psychology began as a result of Timberlake and Allison's theory of response deprivation, but can be traced all the way back to B.F. Skinner in 1938. Skinner's Law of Effect modernized Thorndike's Law of Effect asserting

that if a response is followed by the presentation of a reinforcer, the response will be strengthened which as indicated by increasingly frequent responses (Skinner, 1938). The modification Skinner adopted was that his theory was strictly based on observable behavior whereas Thorndike emphasized concealed connections made within the brain as being responsible for the elicited behavior (Thorndike, 1911). There was, however, one important problem with Skinner's Law of Effect -- it was based on circular logic which, by definition, meant that it was almost impossible to disprove. In other words, by defining a reinforcer solely by its ability to increase the rate of response, Skinner, in effect, said that anything that increases the rate of a response will increase the rate of a response.

In a seminal paper published in 1959, David Premack attacked the circular logic put forth by Skinner in 1938 with his Rate Differential hypothesis. Simply stated, Premack demonstrated that it is the opportunity to engage in the reinforcing behavior that increases the response rather than the object of that behavior. Premack, in a series of experiments, revealed that if a monkey is presented with a choice of two behaviors, the more frequently exhibited behavior can act as a reinforcer for the less common behavior (1959, 1962). This simple demonstration served to nullify the idea of a trans-situational reinforcer proposed by Skinner and again by Meehl in 1950. The complication Premack could not account for was that although certain behaviors hold a high rate of differential, that is to say that the potential reinforcing properties are high, they do not always act as a reinforcer. For example, many children would prefer to be awarded a scoop of ice cream than a spinach salad for a good performance. Consumption of too much ice cream however can induce sickness consequently rendering the ice cream a punisher rather than a reinforcer.

In 1974, Timberlake and Allison took the opportunity to address the problem Premack's theory could not explain. Timberlake and Allison stated that if the ratio of responses per reinforcer during an experimental condition is larger than the ratio of responses per reinforcer obtained during baseline a reinforcing situation will result. This formula became known as the Response Deprivation Theory which holds that in order for reinforcing properties to exist and be maintained the contingent response must be kept below the baseline response rate. Furthermore, Timberlake and Allison claimed that so long as a response occurs at a rate higher than zero, it is possible to deprive the animal of the response to the point where it will perform almost any activity to gain access to the response. Returning to the example of ice cream and spinach then, if, during a baseline condition, a child consumes five scoops of ice cream, the ice cream will maintain it's reinforcing properties as long as the award is below five scoops. Anything more than five scoops of ice cream will act as a punisher. Additionally, if a child was presented with two choices, ice cream or spinach, and one was to only feed the child ice cream, the child would, theoretically, reach a point at which he/she would crave spinach so intensely that, in fact, he/she would do four hours of algebra in order to receive it.

The relationship described in Timberlake and Allison's Response Deprivation Theory is directly comparable to the economic law of supply and demand. The law of supply and demand is a well known theoretical principle of economics which describes an inverse relationship between the quantity of a commodity available in the marketplace and the stable market value of that commodity. In other words, as the available supply of a commodity decreases, the price paid for said commodity will markedly increase and vice versa. If one were to graphically plot the function of the Response Deprivation theory and the law of supply and demand, he/she would find

striking similarities between them.

In 1980, Hursh succeeded in connecting and relating economic theories to the behavior exhibited in operant conditioning chambers. He indicated that the manipulation of an animal's environment could, in fact, produce conditions similar to that of open and closed economies. In behavioral terms, an open economy is established when supplemental feedings outside of the experimental session are regularly dispensed to the animal. Conversely, animals in a closed economy do not receive additional provisions apart from the experimental session. Consequently, in a closed economy the animals entire food ration for the day is acquired within the experimental session. In either open or closed economies, however, the animal's daily food intake is a influenced by its interaction with the supply or reinforcement schedules (Hursh, 1980).

As noted in the above paragraph, the reinforcement schedule an animal is subjected to plays a large part in determining it's daily food consumption. There are four primary schedules utilized in behavioral psychology: fixed ratio schedules, fixed interval schedules, variable ratio schedules, and variable interval schedules. In a fixed ratio schedule, the experimenter assigns the number of responses required for the animal to receive a reinforcer. For example in an FR 6, the animal must perform six bar-presses before it receives a food pellet. Fixed interval schedules are similar in that the experimenter designates an allotted time period that must pass in order for the animal to be reinforced, however the number of bar-presses accomplished within the given time period in no way influences the presentation of the reinforcer. An animal on an VI 10, then, must wait for a ten second interval after which the first response (bar-press) is reinforced. Variable ratio and variable interval schedules work much in the same way as fixed ratio and interval schedules except that the ratio or interval does not directly require a specific number of responses

or time to pass. Instead, the schedules set the average number of responses or time between available reinforcers. For example, on a VI 60 the animal has the opportunity to be reinforced approximately every 60 seconds provided that the animal bar-press after the interval has passed. The actual interval though could be anywhere from 40 seconds to 80 seconds as defined by the Catania and Reynold's 1968 Arithmetic Series. In reality, however, the interval could last as long as 300 seconds or be as short as two seconds. Thus in a fixed ratio schedule, the price (responses/reinforcer) the animal must pay for the commodity is set, whereas in variable interval schedules, the animal determines the price for the commodity. The difference is similar to that of going to a retail store to purchase an item at a fixed price versus bidding for the very same item at an auction.

According to Hursh, the manipulation of these schedules of reinforcement, or food supply, has different effects on the economic demand curves in both open and closed economies (1980). A demand curve is simply a function that relates the quantity of a commodity consumed to the market price (Raslear, Bauman, Hursh, Shertleff & Simmons, 1988). A gradually declining demand curve in the face of increasing prices, also known as inelastic demand, indicates that a large fluctuation in price has very little effect on consumption. Consider, for example, the relative strong hold manufacturers of feminine sanitary products have on women. Should the price of this commodity increase dramatically, consumption will remain fairly constant. In contrast, produce items, such as strawberries, when out of season experience a moderate price increase, however the consumption decreases disproportionately. This phenomena is known as elastic demand. It is illustrated as a rapidly declining demand curve with increasing price, and denotes that a small increase in price markedly decreases consumption.

As noted by Hursh, an operant conditioning environment can adequately simulate situations such as welfare, labor supply, medium of exchange, choice, consumer reports, and perhaps even a family. This is important because in open economies, demand elasticity is often reported. That is, as the price for the commodity increases, response rates decrease, whereas in closed economies this is not demonstrated. Hursh discusses the possibility of substitution from other sources interfering with the economic behavioral output of the animal. In other words, the welfare situation incurred as a result of an open economy may, in fact, decrease the animal's willingness to respond at low rates of reinforcement. The question remaining however, was how the manipulation of supply, rather than price, would effect the animal's subsequent willingness to pay for reinforcers. That is to say that if supply is limited, or inelastic, will the animal be more apt to increase it's behavioral expenditure?

The law of supply and demand suggests that the answer to the above question would be yes. When supply is limited, the price escalates and vice versa (Deaton & Muellbauer, 1980; Bauman, 1991). Recently, Dougan (1992) using variable interval schedules, examined the effect of inelastic supply on the economic behavior of pigeons in an open economy. Variable interval schedules easily simulate the situation of inelastic supply in the sense that regardless of the animal's behavior, the available supply of reinforcers will remain relatively uninfluenced. An animal could pay two responses for a reinforcer or it could pay three hundred, the amount of reinforcers available will remain the same. Dougan demonstrated that pigeons responding on VIs 30, 60, 120, and 240, behave in accordance with the law of supply and demand, thus providing further confirmation of the parallels between economic theory and behavior. Pigeons responding on schedules producing a large quantity of reinforcers (e.g. VI 30) paid relatively few responses

per reinforcer (obtained behavioral cost), whereas pigeons paid a higher price on schedules in which a small number of reinforcers were supplied.

The pigeons in Dougan's study serve to promote the continuing application of economic principles to behavioral experiments. As predicted, the animals demonstrated the law of supply and demand by increasing behavioral output in the face of inelastic supply. The pigeons, however, responded alone in the skinner box without the presence of any other animal. Economists argue that the law of supply and demand is propelled by consumers in the marketplace. Though the results empirically strengthen the relationship between supply and demand, the competitive social stimulus thought to drive economic theory was not present.

Many experimenters have focused on the concept of social competition among animals. For example, in 1987, Whishaw and Tomie discussed the strategies rats utilize for the acquisition and protection of food from other rats. They studied the immobile posture rats adopt while eating which consequently renders them vulnerable to attack by other rats. Whishaw and Tomie also noted that rats venturing to seize food from another rat subtly advance from the posterior or rear. It is possible to conclude that the positioning of animals in an operant chamber will facilitate the creation of a competitive atmosphere. This is important to note because the barrier utilized to restrict social interference in the following experiments situated the target rat behind the subject rat.

A comparative study performed by Hole in 1991 analyzed the effects of restricted social deprivation versus no access on the social behavior of rats. The results of this research indicates that rats demonstrate marked increases in social play following the elimination of social contact in comparison to measures of play displayed by control animals allowed unrestricted social

communication. The findings show that the most significant increase in social play occurred during the first forty minutes of the experimental session. Hole further suggests that one hour of social contact is an adequate amount of social stimulation for the appeasement of any biologically or developmentally necessary requirement. Hole's study may provide insight into the reinforcing qualities of social communication and its role in the economic behavior of rats.

Very little research has been conducted that examines economic behavior and tendencies for social competition. Thus far, it is unclear as to how they interact. Economic theory suggests that the presence of competitors should "steepen" the demand function seen in the law of supply and demand. The following experiments therefore, examine whether the presence or absence of a perceived competitor will alter the supply and demand functions Dougan described in the earlier experiment. For hypothetical purposes, two possibilities might occur: 1) the proclivity for social interaction will interfere with the economic behavior or the rat, and/or 2) the presence of a second rat will facilitate economic behavior via a competitive atmosphere.

EXPERIMENT I

METHOD

Subjects

Subjects were six Long-Evans hooded rats, approximately 9 months of age at the beginning of the experiment, obtained from the breeding colony at Illinois Wesleyan University Department of Psychology. All animals were housed individually in hanging stainless steel cages and given free access to water in the home cage. Two additional female Long-Evans rats served as target rats. Targets had free access to both food and water.

Apparatus

The apparatus was a standard operant chamber for rats with the following measurements. The inside of the chamber is 29.5 cm high by 26.5 cm wide by 27.5 cm long. The ceiling and two side walls were Plexiglas, the front and back walls were stainless steel, and the floor a wire grid. A five-watt bulb in the upper left corner served as the house light. The front wall contained two response levers, each 6 cm wide and projecting 1.5 cm into the cage. The bars were 8 cm apart and 8 cm above the floor. A pellet dispenser was 2 cm above the floor and settled between the tow bars. Only the right bar was used during the study. A five-watt stimulus bulb was located behind a 2.5 cm opaque plexiglass disk on the front wall, approximately 6 cm above each bar.

A 27.2 cm high by 26.1 cm long plexiglass barrier was placed in the operant chamber, parallel to the front wall. This device divided the chamber into two sections, the front section being 16 cm deep and the back section measuring 10 cm deep. The barrier completely separated the two sections except for a 3 cm opening between the top of the barrier and the ceiling of the chamber. The barrier was kept in place by another piece of plexiglass bolted perpendicularly to the barrier using stainless steel hinge brackets.

Data collection and experimental events were recorded using an IBM PC compatible computer, using MED-PC software and MED Associates interface. The computer and interface were both located in an adjacent room.

Procedure

All subjects were maintained at 80% of their *ad libitum* weight. Subjects were hand-shaped to respond to the right response lever. The experiment began when all subjects were reliably pressing the bar for food (45 mg pellets, Noyes Improved Formula-A).

Each subject responded to a series of four experimental conditions defined by variable interval schedules ranging from a high rate of reinforcement to a low rate of reinforcement (VI 30, VI 60, VI 120, VI 240). The sequence of conditions were counterbalanced to prevent any ordering effects. Each condition ran for 12 days for a total of 48 sessions. During each of these conditions, a target rat was present for six sessions, pseudo-randomly alternated with non-target sessions in such a way that neither condition occurred for more than two consecutive sessions. At the beginning of each target present session, the target was placed in the back half of the chamber and served as a competitive stimulus. The subject rat was placed in the front of the chamber where it bar pressed for food. The barrier was kept in position for all conditions regardless of the presence or absence of the target rat in order to maintain a constant apparatus construction.

RESULTS AND DISCUSSION

Results were calculated by computing the average cost per schedule of reinforcement for the last four days of each condition (target and no-target). The obtained behavioral cost was calculated by dividing the number of responses during a session by the number of reinforcers in a session.

Figure 1 represents the mean cost for each subject plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions. Several points can be made by examining these graphs. First of all, excepting animals 4 and 5, these results all support behavioral economic theory in that subject response produced a downward sloping demand curve. Secondly, all subjects, at the lowest reinforcement rates, responded more without the target rat (competitive stimulus) than with the target present. Third, the results of all subjects support

inelastic supply predictions excepting one point for subjects 4 and 5. These were also the only two subjects not to demonstrate clear differences between the presence and absence of the target rat. Finally, not only were there very distinct demand curves for most subjects, but there were very clearly two differences between the target and no-target conditions: 1) subjects always responded more without the lure present, and 2) subjects responded significantly less during low rates of reinforcement when the target was present.

[Insert Figure 1 about here.]

Figure 2 represents the mean cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions. Both conditions produce a descending function demonstrating the inverse relationship between cost and quantity as predicted by the law of supply and demand. The target absent condition appeared to enhance this relationship, in that it generally produced a higher cost than the absent condition. That is, on schedules providing low quantities of reinforcement, the presence of the target rat apparently reduced the behavioral cost relative to the target absent conditions.

[Insert Figure 2 about here.]

A Two-Way Within-Subjects Analysis of Variance revealed a significant effect of reinforcement quantity across schedules ($F[3,15]=14.75$, $p<.001$). There was also a significant interaction effect between reinforcement quantity across schedules and the presence or absence of the target rat ($F[3,15]=4.71$, $p<.025$). There was no significant effect of the presence of the target rat ($F[1,5]=4.43$, $p>.05$).

The significant effect of reinforcement quantity shows that behavioral cost changed as a function of quantity of reinforcers available. In other words, price was elastic. The significant

interaction indicates that price changes differently depending on whether the target rat is present or absent.

As previously stated, the results of this study serve to maintain and support current behavioral economic theories. The subjects clearly responded at high levels for few reinforcements. In other words, similar to that of the law of supply and demand, as the price increased the rat was willing to work more diligently and spend more in terms of response in order to obtain the commodity. In the presence of another rat, however, the subject responded less than if it were left undisturbed. The results obtained suggest that influences other than those of economic theories are interfering with subject response.

Again, the results indicate that in the presence of the target rat the subject rat reduced responding. One could view the situation created by the barrier, keeping the target rat behind the subject, as a possible explanation. Similar to the Whishaw and Tomie experiment in 1987, the subject may have sensed a threat of competition for the food the rat received as a reinforcer. It is perhaps possible to say that instead of the subject expending effort for reinforcers that would benefit the target through seizure, the subject failed to allow an opportunity for theft. In other words, the lower response rates were a result of protective measures the subject utilized to guard the food the subject labored to obtain.

Another plausible explanation for the results found in this experiment is social deprivation. Hole found in his 1991 study that there were marked increases in social play exhibited following restricted access in social contact. The rats used in this study were housed individually in hanging cages and not allowed access to social contact. One may conclude that the decrease in response rates when in the presence of a target rat was a result of a more potent reinforcer, social contact

and communication. It is therefore conceivable that the social stimulation afforded by the presence of the target rat outweighed the reinforcing properties of the food pellets as a result of the social isolation incurred by the individual housing of rats. In other words, the rats were more interested in investigating and playing with a mate than they were about working for food pellet reinforcers.

Another viable explanation is that the target rat did not undergo food deprivation; thus, the subject rat failed to perceive the target rat as a competitor.

A more likely reason for the results is the flaw in the apparatus design. The barrier was not tall enough to completely separate the chamber. It was not anticipated at the beginning of the study that the food deprived rats would be able to climb over the barrier. Casual observation suggests that they often engaged in such behavior. It is possible that the subjects found climbing the barrier more exciting than working for reinforcers. Moreover, by climbing the barrier the subject was able to enjoy complete social contact with the target rat. Therefore, the lower response rates could be the result of the rat jumping the barrier and either not being able to climb back over or finding the other side of the barrier more reinforcing because of the contact with the target rat. Replication of the study must be performed prior to discussing the results supportive or inconclusive qualities. Suggestions for further study would be to keep the animals in a social environment with unrestricted access to one another and the repeat the experiment to see if the results were obtained because of social deprivation. Experiment 2 will address these issues.

EXPERIMENT 2

In 1991, Hole found that rats do indeed exhibit increases in social play following restricted access to social contact. The design flaw found in the barrier utilized in Experiment 1 facilitated

social communication between the contact-deprived rats. In order to determine the role of social contact and deprivation, Experiment 2 is designed to allow the rats to mingle in the home cage and in the operant chamber.

METHOD

Subjects

Subjects were 12 Long-Evans hooded rats, approximately 9 months old at the beginning of the study, obtained from the Illinois Wesleyan University animal colony.

Apparatus

The operant chamber and barrier used in Experiment 1 was used in Experiment 2 with no modifications. As noted below, each subject was assigned a target rat to be housed with. The housing apparatus was a polyethylene translucent cage with the following measurements. The cage measured 17 and 1/2 inches long by 9 and 1/2 inches wide with a depth of 7 and 3/4 inches. Each cage was layered with a corn based cob for comfort and absorption of feces. This cob was changed approximately every three days, according to IWU laboratory regulations.

Procedure

The procedure used in Experiment 2 was the same as that in Experiment 1 with the following modifications: 1) each subject was assigned and housed with a target rat, identified by an ear tag, in a polyethylene translucent cage, and 2) all animals (including targets) were subject to food deprivation and maintained at 80% of their free feeding body weight. Supplemental feeding time was characterized by the researcher handing each rat a piece of chow to ensure that they were receiving the food supplied. No other procedural differences were implemented.

RESULTS AND DISCUSSION

Results were calculated in the same fashion as that in Experiment 1. The obtained behavioral cost (responses per reinforcer) was calculated as in Experiment 1.

Figure 3 represents the mean cost for each subject plotted as a function of quantity of reinforcers supplied under conditions of target present and absent. Although the majority of animals illustrate the inverse relationship between quantity and cost and inelastic supply predictions seen in Experiment 1, the depiction is not nearly as clear.

[Insert Figure 3 about here.]

A Two-Way Within-Subjects Analysis of Variance reveals that similar to Experiment 1, there was a significant effect of reinforcement quantity across schedules ($F[3,15]=10.6$, $p<.001$). Again, like Experiment 1, there was no significant effect of the presence of the target rat ($F[1,5]=.626$, $p>.05$). Figure 4 represents the mean cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions. This function clearly shows the same inverse relationship between quantity and cost seen in Experiment 1. Although the target absent condition appears to amplify the demand elasticity on all schedules in that they generally result in higher behavioral expenditure, the target present condition produced no significant change in behavior relative to the target absent condition ($F[3,15]=.04$, $p>.05$).

[Insert Figure 4 about here.]

Like Experiment 1, the present results failed to confirm the hypothesis that the presence of a competitor would increase the obtained behavioral cost relative to the condition in which the competitor was absent. The present results differed from Experiment 1 in that there was no difference between lure present and lure absent conditions.

It is particularly noteworthy that Experiment 1 and Experiment 2 failed to confirm the hypothesis in different ways. In Experiment 1, the obtained results completely contradicted the hypothesis. This could have been because social deprivation incurred by traditional secluded housing made the competitor a social stimulus, eliciting social behavior incompatible with bar pressing. Alternatively, the competitor may not have been perceived as a threat because it was not food deprived. The above problems were corrected in Experiment 2, in which both rats were housed together and both rats were food deprived. The results of Experiment 2 were also "closer" to the predicted results than those of Experiment 1. In other words, remediation of conflicting factors in Experiment 1 produced results more clearly in line with economic theory.

The question remains whether further procedural adjustment will produce results more consistent with the original hypothesis. For example, it was discovered that the rats were able to cross the barrier, and did so frequently in Experiment 2. Thus, the rats were able to interact in ways unanticipated at the beginning of the experiments. If the rats engaged in aggressive or directly competitive behavior, this too could move results away from predictions. The next study, Experiment 3, will utilize an improved barrier, and may produce results more consistent with hypotheses.

EXPERIMENT 3

Economic theory suggests that the presence of competitors should "steepen" the demand function called for by the Law of Supply and Demand. Experiment 3 allows for social stimulation within the home cage but not in the operant chamber in hopes that it accurately simulates a competitive environment. Experiment 3 addresses the issue of the barrier design flaw mentioned in both Experiment 1 and 2. An improved barrier was constructed to completely separate the front

and back of the operant chamber, rendering the opportunity for social contact in the experimental setting impossible.

METHOD

Subjects

The subjects utilized in Experiment 3 approximately 16 months old at the start of the study. A separate target rat was assigned to each subject rat. Each pair was housed together as in Experiment 2. Target rats were identified by a blue mark on the superior side of the tail. All rats were given free access to water in the home cage.

Apparatus

The apparatus utilized in Experiment 1 and 2 was identical in Experiment 3 with one significant modification. Two pieces of plexiglass measuring 2.5 cm high and 26 cm long were bolted to the ceiling of the operant chamber perpendicularly using stainless steel hinge brackets. 1 cm separated the two pieces of plexiglass and served to close off the 3 cm gap allowed by the barrier alone.

Procedure

The procedure implemented in Experiment 2 was replicated in Experiment 3.

RESULTS AND DISCUSSION

As in Experiment 1 and 2, the results were calculated by computing the average cost per schedule of reinforcement for the last four days of each condition (target and no-target). The obtained behavioral cost was calculated by dividing the number of responses during a session by the number of reinforcers in a session.

Figure 5 represents the mean cost for each subject plotted as a function of quantity or

reinforcers supplied for both target present and target absent conditions. Excepting data points from the target absent condition for animals 1,3,4, and 6, these results all support behavioral economic theory in that the collective subject response produced a downward sloping, or elastic, demand curve. Excluding animals 1 and 2, each subject, at the lowest rates of reinforcement, responded more without the target rat than with the target present.

[Insert Figure 5 about here.]

Figure 6 represents the mean cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions. Both conditions produce a descending demand function illustrating the inverse relationship between cost and quantity as predicted by the law of supply and demand. There is no clear relationship displayed between the target present and target absent conditions, though there is certainly more interaction exhibited in Experiment 3 than in Experiments 1 and 2.

[Insert Figure 6 about here.]

As seen in Experiments 1 and 2, a Two-Way Within-Subjects Analysis of Variance discloses a significant effect of reinforcement quantity across schedules ($F[3,15]=14.57$, $p<.001$). Like Experiment 2, however, there was no significant interaction between reinforcement quantity across schedules and the presence or absence of the target rat ($F[3,15]=1.86$, $p>.05$). Furthermore, there was no significant independent effect of the presence of the target rat on subject behavior ($F[1,5]=.382$, $p>.05$).

The results obtained in Experiment 3 were, again, inconsistent with the predictions. It was anticipated that the modification to the barrier which would bar any physical interference from the target rat, would allow the subject rat to respond uninterrupted thus steepening the demand

function. In all scheduled rates of reinforcement, except VI 240, the subject's economic behavior is aggressive. The exception may be due to the social stimulation created as a result of the presence of the target rat and the positioning of the animals in the chamber. That is to say that at low rates of reinforcement, the subject becomes "disinterested" in bar pressing and seeks social communication with the target rat instead. As another possibility, due to the positioning of the rats, the target rat is not normally within the subject's visual field when the subject is actively bar pressing. Thus, at low rates of reinforcement, the target rat might act as a distraction rather than a competitive stimulus for active economic behavior.

Another plausible explanation is that at low rates of reinforcement in an open economy, the subject simply lacks the motivation to increase behavioral output because the supplemental feedings interfere with any biologically driven need to acquire food.

A more likely reason for the outcome of Experiment 1,2, and 3, is that because the target rat is not visually accessible in the present experimental arrangement that the subject does not perceive the target rat as a competitor at all. Clearly, more research is necessary to determine which, if any, of these factors is responsible for the failure to confirm predictions.

GENERAL DISCUSSION

The present experiments extend Dougan's (1992) economic analysis of variable interval schedules. According to his analysis, the behavior of rats on interval schedules should conform to the economic law of supply and demand. That is, there should be an inverse relationship between obtained behavioral cost and quantity of reinforcer supplied. This was found in Experiments 1, 2, and 3, both in the presence and absence of the competitive target.

Experiment 1, 2, and 3, however, failed to confirm the hypothesis that a competitive

stimulus would drive up the obtained behavior cost. According to economists, the law of supply and demand is driven by competition among consumers in the marketplace. The presence of a competitor should thus increase the obtained market price, or behavioral cost in the present experiments. In Experiment 1, the presence of a lure reduced cost relative to the target absent condition, a result opposite that predicted by economic theory. In Experiments 2 and 3, there was no significant difference between target present and target absent condition.

The purpose of these studies was intended to address the issue of competition driving the law of supply and demand as theorized by economists. Although these experiments did not confirm all hypotheses, they do, however, further confirm, the results of Dougan's 1992 study in that in economic situations where there is inelastic supply, behavioral output is increased..

FUTURE DIRECTIONS

The following experiments, termed the Two-Feeder Studies, stem directly from the previous group, specifically Competition study 1. In the discussion, further research was suggested utilized an operant chamber that would allow the subject and target rat to be side by side as opposed to the target being located behind the subject. Due to the positioning of the animals and equipment constraints in the Competition Studies, the subject, if pressing the bar, could not see the target, thus, it is conceivable that the presence of the target rat served to distract rather than stimulate the subject. In other words, it is possible that the lure rat was not perceived as a competitor as a result of the position of the barrier. The following experiments would employ a specialized operant chamber that contains two food dispensers located next to each other on the front wall. Consequently the animals would be competing in full view of each other. Another unique feature of the Two-Feeder studies is that both animals would be actively engaging in lever

response behaviors rather than only one as in the Competition studies. The differences is similar to that of running a race alone in front of a group spectators verses running against a competitor. The result of this modification should yield a more competitive atmosphere for the animals to respond in.

The purpose of this set of experiments, then, is to investigate the effects of indirect and direct social competition on the economic behavior of rats. The Two-Feeder Studies are a result of sheer curiosity; they were spurred on by the possibility that the position of the rats in a competitive environment might influence the behavior elicited. In a sense, the Two-Feeder Studies attempt to further explain the results of the Competition Studies. One of the remaining questions in that group was whether or not the target rat was a distraction or actually a competitive stimulus. By arranging the rats so that they are in full view of each other increases the potential for creating a competitive atmosphere in that the subject, rather than turning it's attention away from the response lever to view the target, is still in a position to respond. Furthermore, the rats would both be actively engaging in bar-pressing responses thereby increasing the potential for a truly competitive atmosphere. As mentioned previously, this modification significantly alters the situation from a competition with oneself to a competition with another individual. This change should further stimulate and more accurately simulate a competitive environment.

Another particularly interesting avenue for further research is to replicate the Two-Feeder Studies mentioned with humans. Amy Parker, last year, demonstrated the law of supply and demand using VI schedules in a human study utilizing a computer video game. With this technology it would be impossible to compare the responses made by rats and humans and perhaps demonstrate a successful application of economic principles within the realm of behavioral

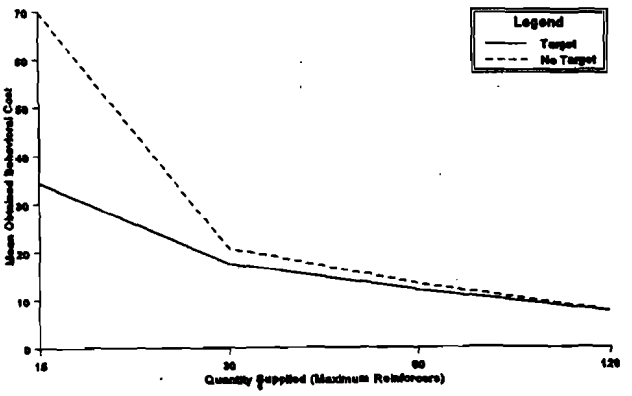
psychology.

Figure 1.

Figure 1 represents the mean obtained behavioral cost for each subject plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

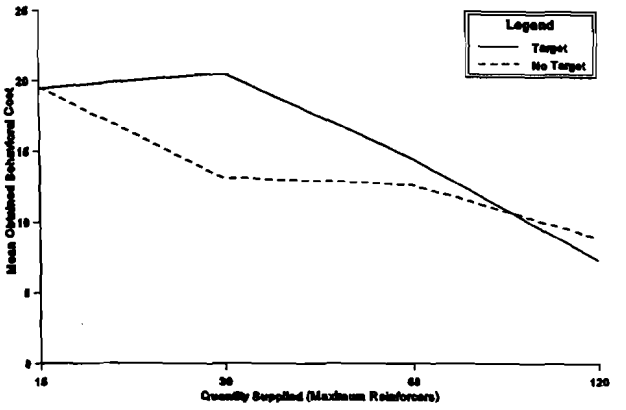
Competition Study I

Animal 1



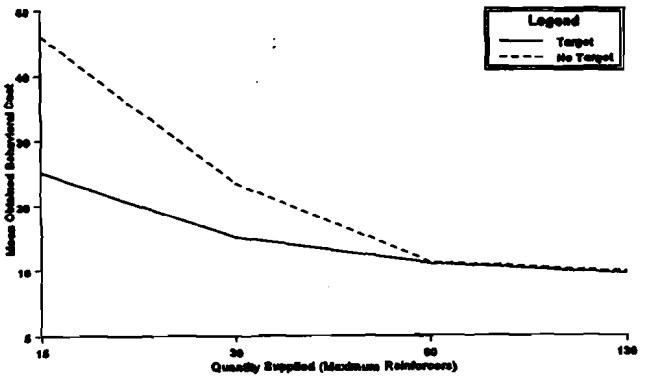
Competition Study I

Animal 4



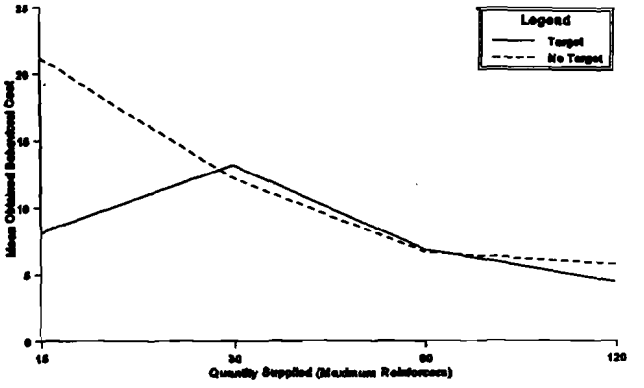
Competition Study I

Animal 2



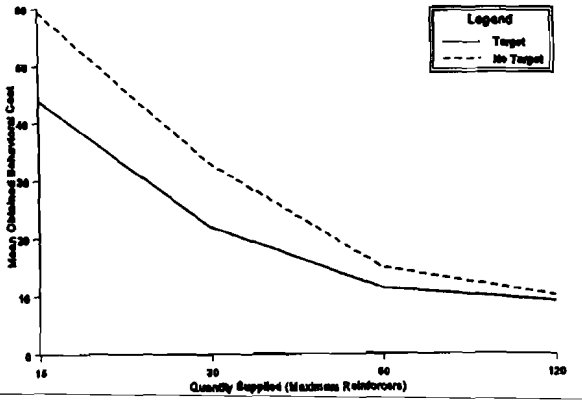
Competition Study I

Animal 5



Competition Study I

Animal 3



Competition Study I

Animal 6

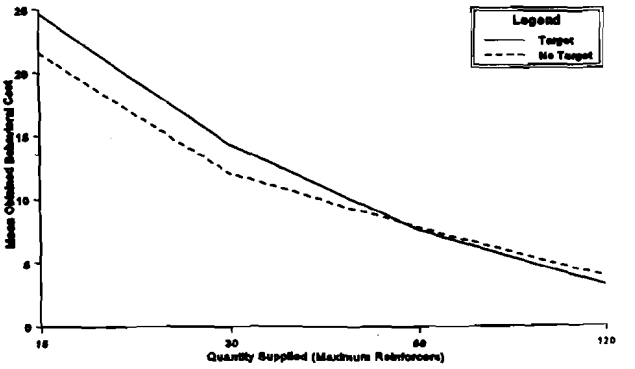


Figure 2.

Figure 2 represents the mean obtained behavioral cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

Competition Study I

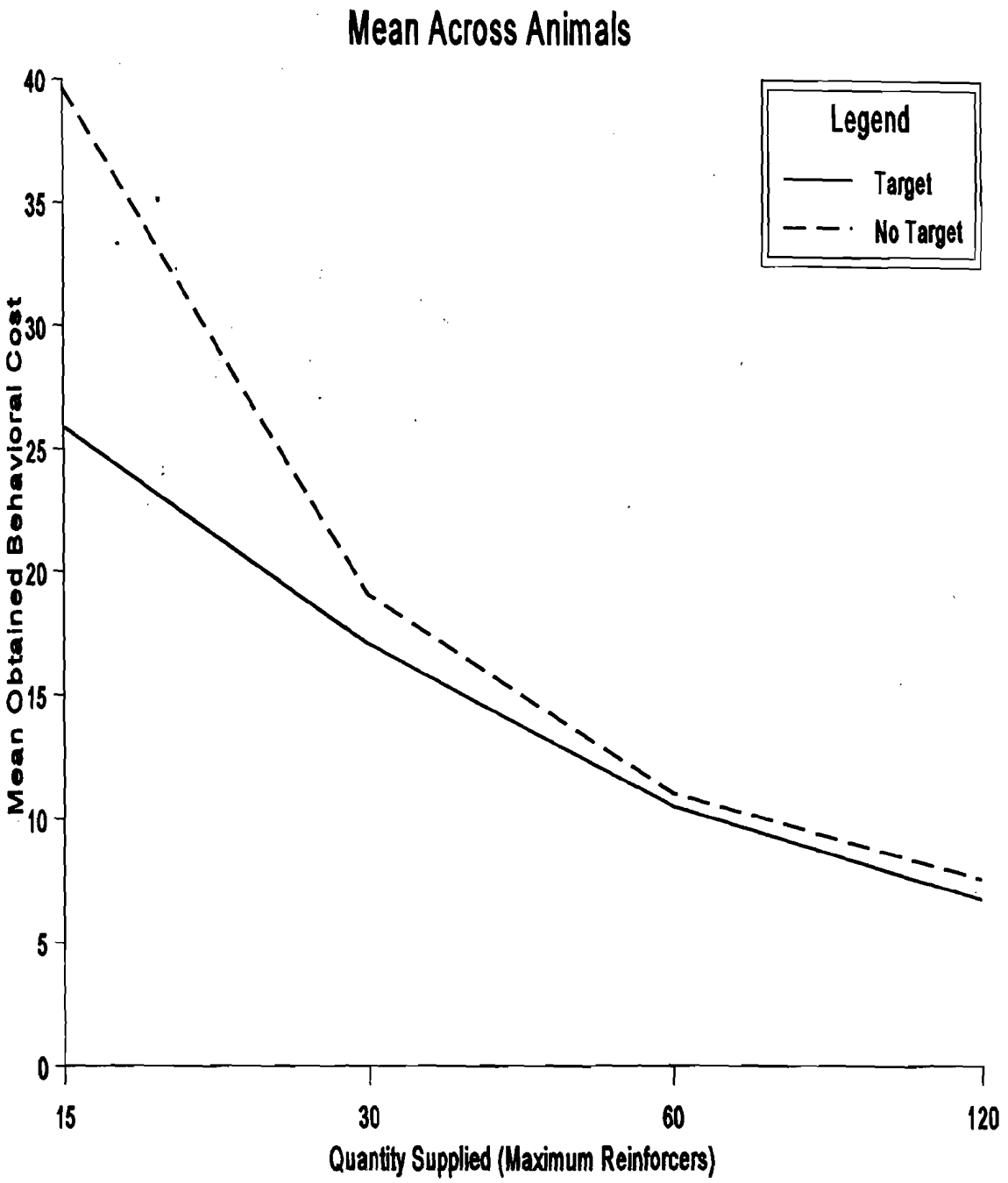
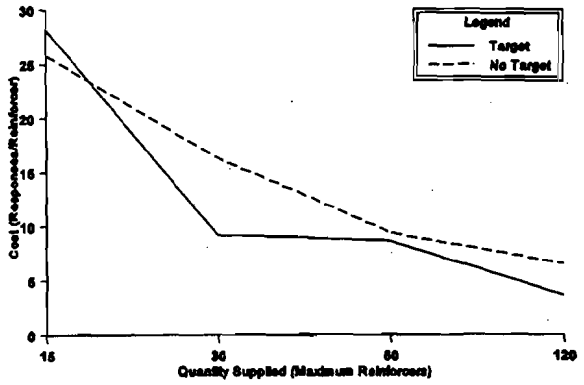


Figure 3.

Figure 3 represents the mean obtained behavioral cost for each subject plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

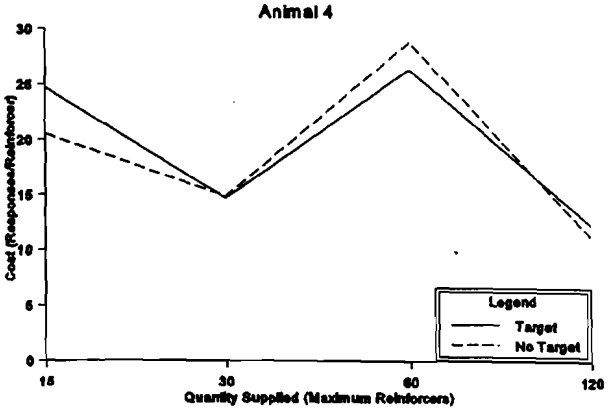
Competition Study II

Animal 1



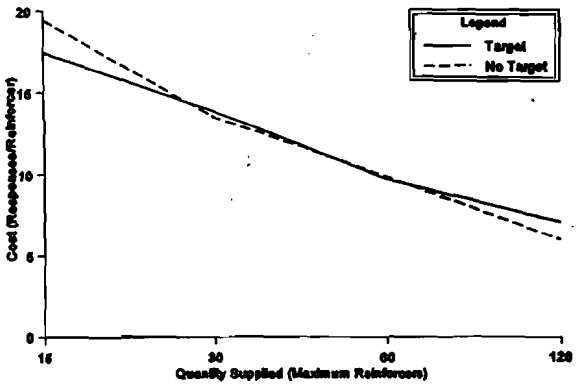
Competition Study II

Animal 4



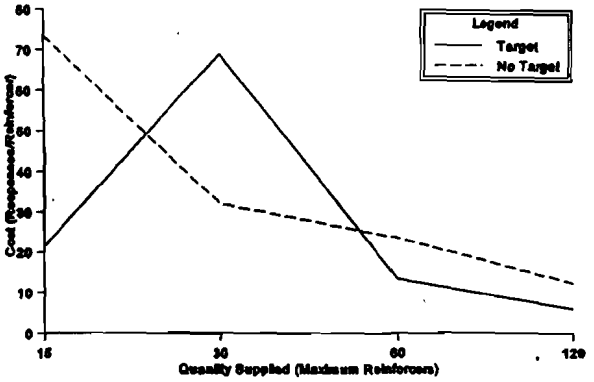
Competition Study II

Animal 2



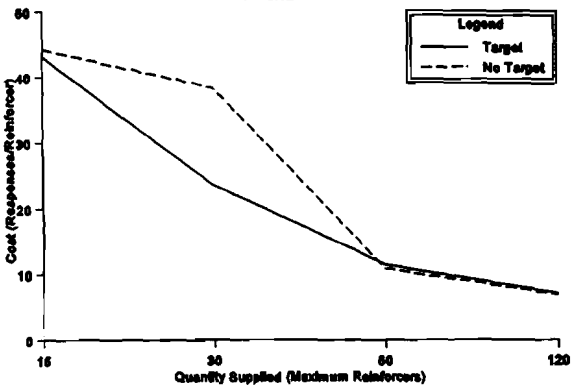
Competition Study II

Animal 5



Competition Study II

Animal 3



Competition Study II

Animal 6

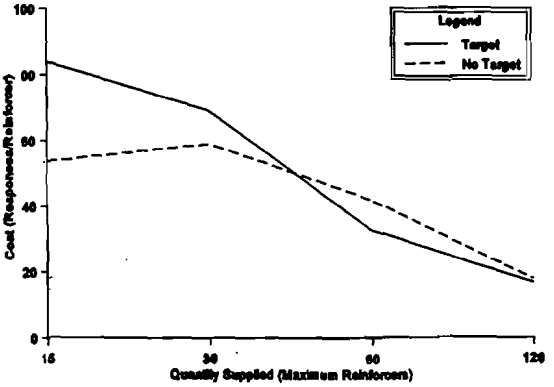


Figure 4.

Figure 4 represents the mean obtained behavioral cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

Competition Study II

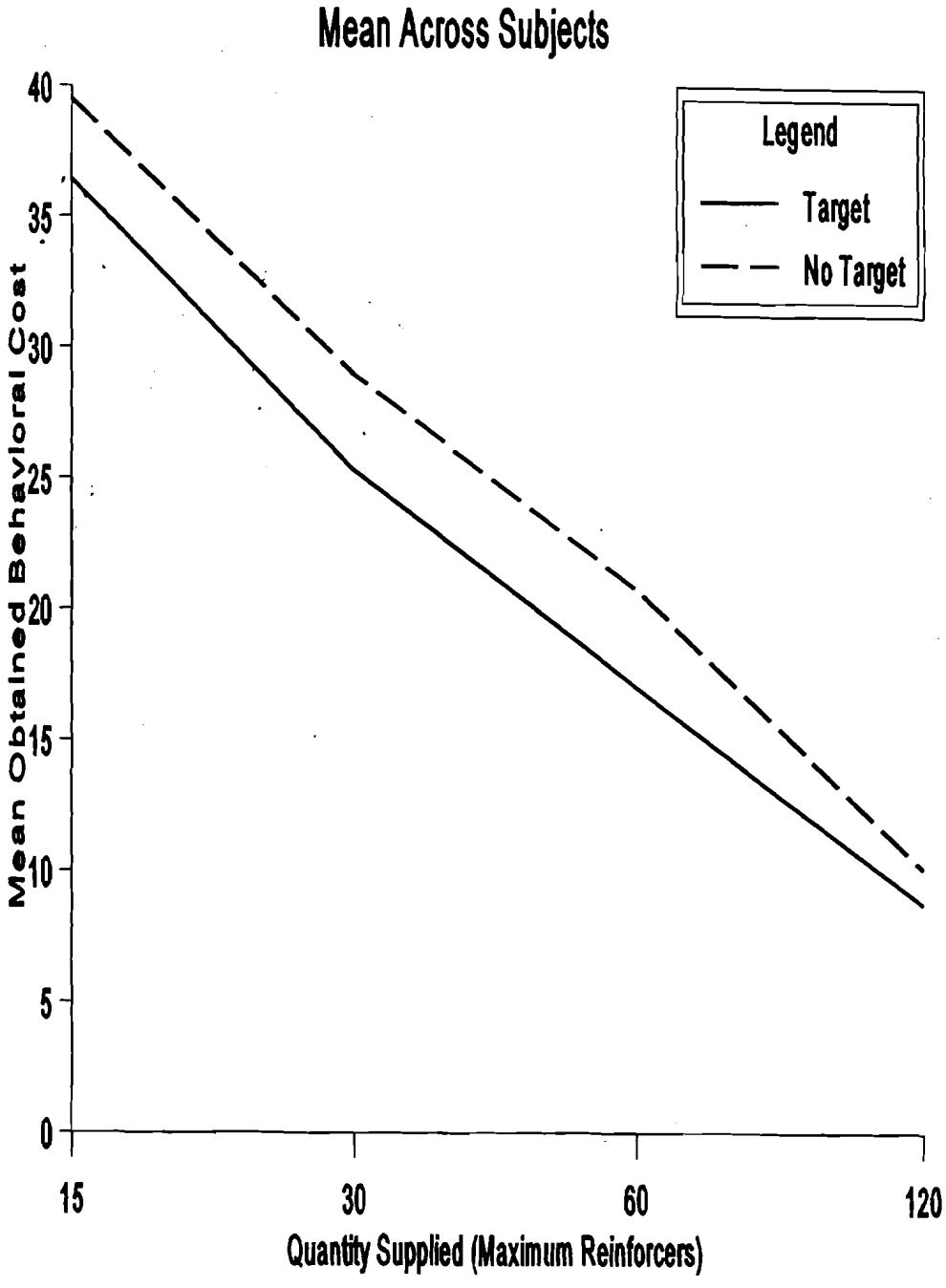
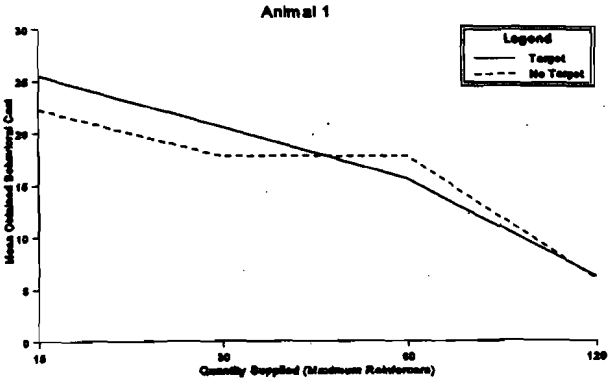


Figure 5.

Figure 5 represents the mean obtained behavioral cost for each subject plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

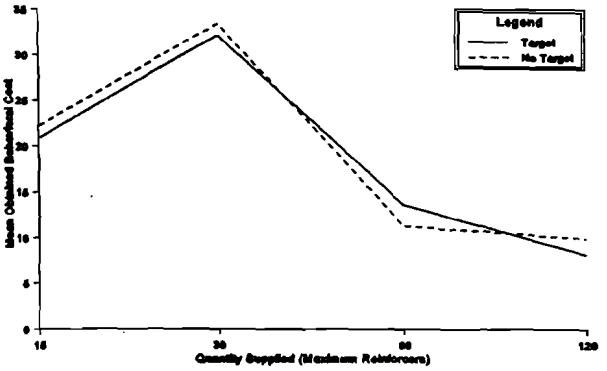
Competition Study III

Animal 1



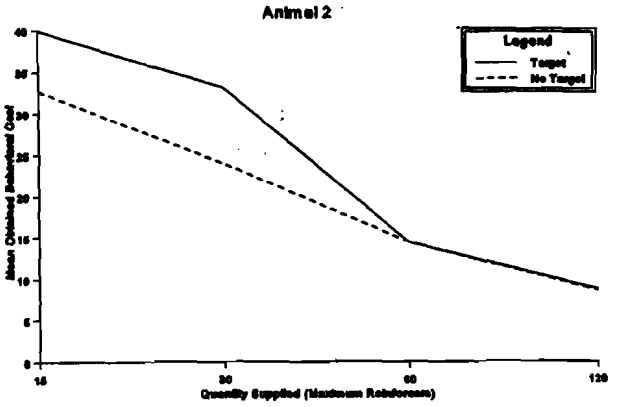
Competition Study III

Animal 4



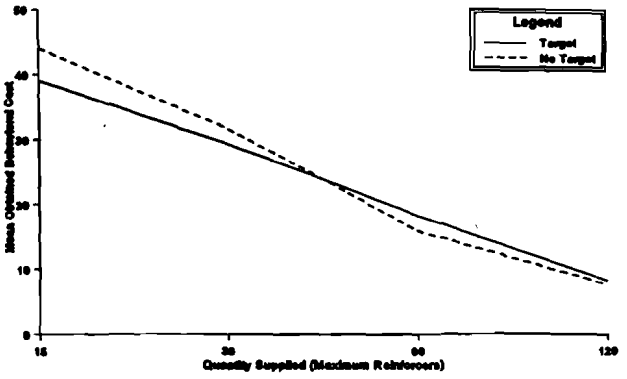
Competition Study III

Animal 2



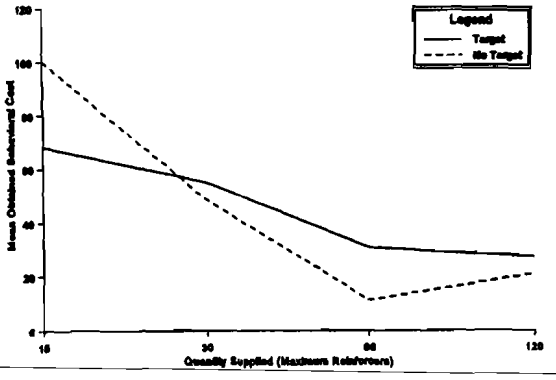
Competition Study III

Animal 5



Competition Study III

Animal 3



Competition Study III

Animal 6

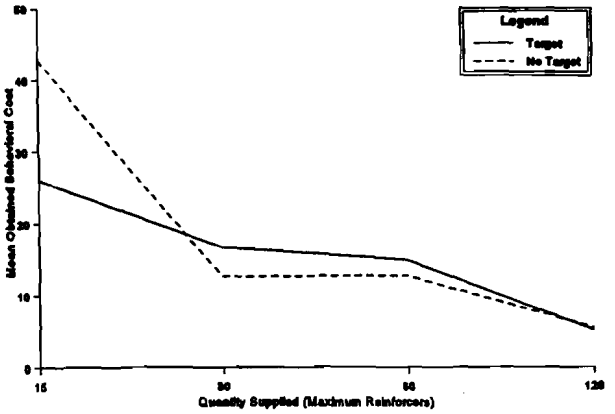
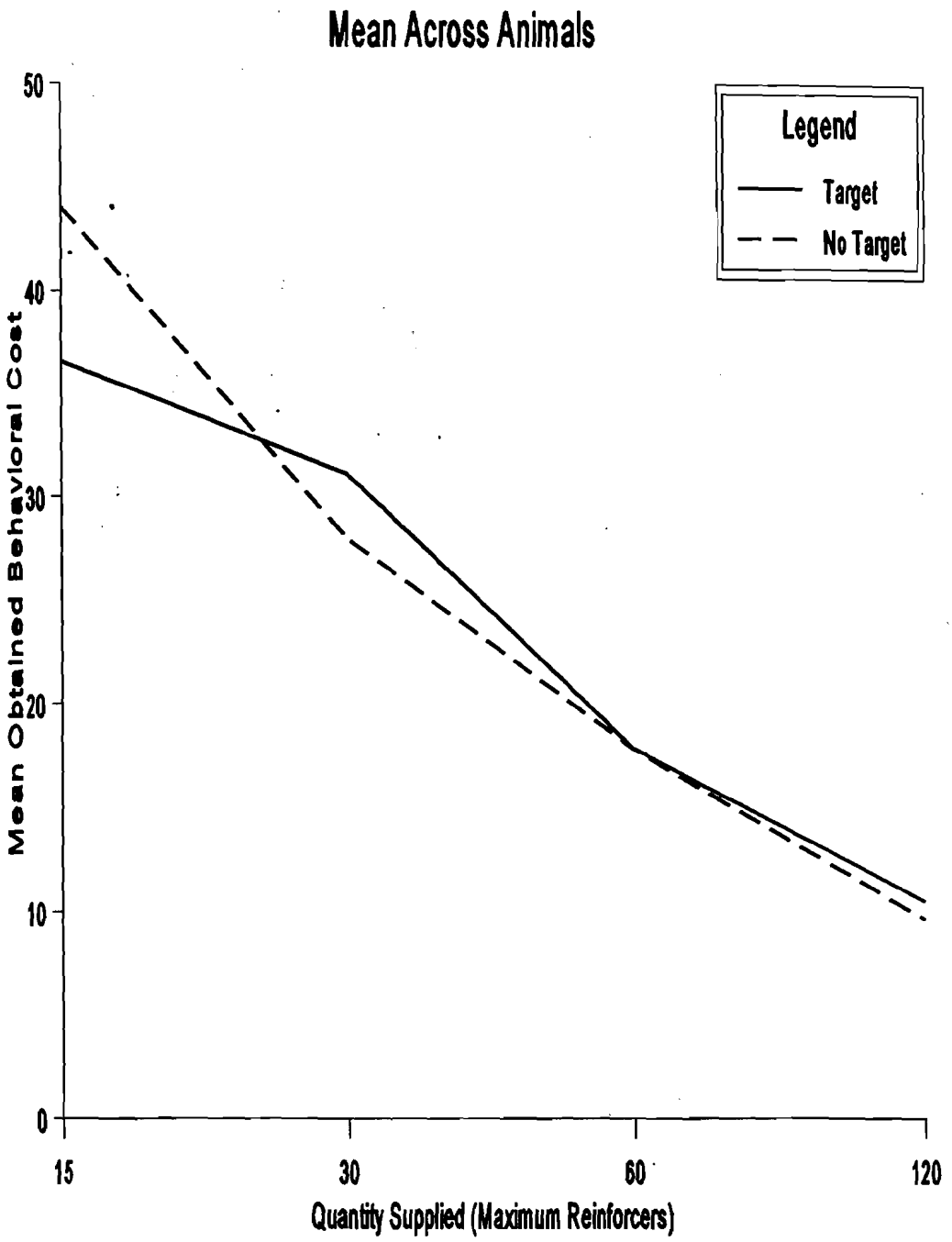


Figure 6.

Figure 2 represents the mean obtained behavioral cost across animals plotted as a function of quantity of reinforcers supplied for both target present and target absent conditions.

Competition Study III



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