Experimental Studies of Consumer Demand Behavior Using Laboratory Animals

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EXPERIMENTAL STUDIES OF CONSUMER DEMAND BEHAVIOR USING LABORATORY ANIMALS*

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Using laboratory animals as subjects, two series of experimental studies of consumer demand behavior are reported. The experiments show that laboratory animals will change consumption patterns in response to changes in the budget set, consuming more of the lower priced commodities and less of the higher priced commodities. Large rotations in the budget line for essential commodities resulted in severe disruption of consumer behavior. The experiments demonstrate the feasibility of using non-human subjects in laboratory studies of economic behavior.

Ever since Darwin it has been widely recognized that behavior and structure vary continuously across species and that behavioral principles do not stop suddenly at the boundary separating humans from other animals. The dimensions of this variation have been of interest on purely intellectual grounds to numbers of psychologists, ethologists, biologists, and ecologists. Determining the dimensions of this variation in economic behavior between humans and non-humans is of interest for this same reason. Studying the variations in behavior across species is also of interest on practical grounds, for if it can be established that analogous economic processes exist across species, our chances of finding out more about these processes are vastly increased by experimenting with laboratory animals.

Two series of experimental studies of consumer demand behavior that use white male albino rats as subjects are reported. In one experiment the commodities over which the budget set was defined consisted of root beer and Tom Collins mix, with food and water available at all times in unlimited amounts. In the other experiment the commodities in the

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budget set consisted of food and water, with no other consumption commodities available outside the budget set. In conducting the experiments our primary goal has been to determine whether laboratory animals would change consumption patterns in response to changes in the budget set and whether the behavior observed could be characterized by members of the class of Slutsky-Hicks demand functions. Condition (1), stated below, suggested an experimental design which would achieve this goal.

$$(1) \qquad \text{If } p^i \neq p^j \text{ and } p^j x^i = p^j x^j \text{ then } (p^j - p^i)(x^j - x^i) < 0$$

where x^i and p^i are placeholders for the n-vector of non-negative real numbers that represent, respectively, a commodity bundle purchased by an individual consumer and its price vector. Condition (1) is a necessary condition that all members of the class of Slutsky-Hicks demand functions must satisfy. Demand behavior that does not satisfy Condition (1) is inconsistent with consumer demand behavior as characterized in the Slutsky-Hicks theory.

Experimental studies of the consumer demand behavior of laboratory animals have several intrinsic advantages over studies using human subjects. Placing laboratory animals in an experimental chamber and using automatic programming equipment both to deliver and to record consumption of commodities reduces the error in making and reporting observations of individual price and consumption data to a negligible magnitude (at a fraction of the cost of a comparable experiment on human subjects). Working with laboratory animals also allows us to conduct experiments and change economic parameters in ways that would be unacceptable on both ethical and legal grounds with human subjects. Further, in working with laboratory animals we can control for a substantially greater number of environmental factors affecting behavior than we can with human subjects. That is, placing an animal in an experimental test chamber reduces experimental "noise" to a negligible magnitude compared to studying human behavior in controlled economic environments or in national economic systems.

In using laboratory animals to study behavior, when the ultimate interest is human behavior, a question of paramount importance is the degree of generality of behavioral variables and processes across species. The resolution of this question requires the formation and actual empirical testing of hypotheses across species, and it would be counterproductive to attempt to resolve this question on the basis of alleged *a priori* knowledge. When one variable or process is shown to be applicable to both humans and non-humans we gain additional confidence that other variables and processes will generalize, directly or indirectly, across species.

In this respect, the success of experimental psychologists in using controlled experiments with laboratory animals to complement their studies of human behavior provides a promising basis upon which to begin studies of human economic behavior using non-human subjects.

In reporting the experiments we adhere to the traditional format used in reporting experimental studies of animal behavior in psychology. This format has proved to be an economic means of transmitting the information necessary to evaluate fully the results presented and, more importantly, to enable independent replication of the research.

I. ROOT BEER – COLLINS MIX EXPERIMENT

Subjects

Two white male albino rats, one of the Wistar stock and the other of the Sprague-Dawley stock, were used. Both subjects were between 90 and 120 days of age at the beginning of the experiment and had no previous experimental history.

Apparatus

The experimental data were obtained in two different laboratories using equipment manufactured by Ralph Gerbrands Co., Arlington, Mass. Each subject was individually housed in an experimental chamber measuring approximately 13¼ in. long, 11½ in. wide, and 14 in. high. Two metal levers, projecting 11/16 in. into the chamber, were located on the back panel of the chamber wall, 4 in. above the wire mesh floor and spaced 6½ in. from center-to-center. Root beer and Collins mix were delivered from separate dipper feeder mechanisms located behind the panel on which the levers were mounted. Depression of a lever resulted in the presentation of a dipper cup which was exposed through a recessed tray in the wall of the cage at about floor level directly below the lever. Standard operant programming equipment was used to control the number of depressions of each lever required for a single delivery of a dipper cup, the amount of time a dipper cup remained available, and the total number of lever presses available for operating the dipper cups within any given time period. Two sets of 7-watt white lights, one over each lever, were lit whenever lever presses were available for operating the dipper cups within an observation period. During each presentation of a dipper cup the lights over the controlling lever were extinguished and the other lever was made inoperative. The lights over both levers were extinguished when the subject's allotted presses had been exhausted. A single, 7-watt white houselight, located on the ceiling of the chamber, remained on at all times. The dipper feeder mechanism had interchangeable cup sizes holding .025, .05, .1, .2, and .3 ml of fluid respectively. The experimental chamber and

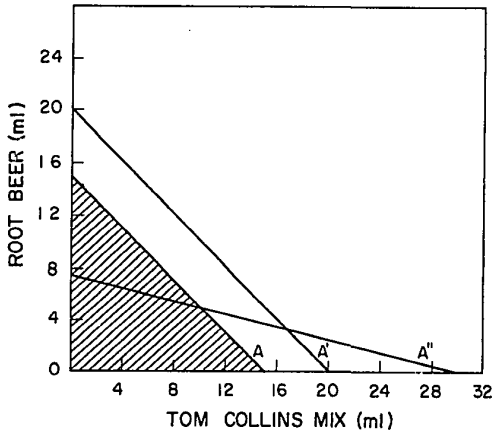
dipper assemblages were completely enclosed in a sound-insulated box. Constant level white masking noise was used to minimize the effect of extraneous noises. Water was provided from a gravity tube located on the chamber door and standard laboratory rat chow was provided in a cup on the cage floor.

The number of depressions of each of the levers, the number of presentations of each of the dipper feeder mechanisms, and the time taken to expend the allotted number of bar presses were automatically recorded.

Procedure

A single response on the left lever resulted in the presentation of a dipper cup containing root beer while a single response on the right lever produced a dipper cup containing Collins mix. During the initial shaping period and the initial (baseline) experimental conditions a .05 ml dipper feeder cup was available for 5 seconds, more than enough time for the subject to consume the liquid. Each subject had a limited sum of lever presses available for operating the dipper cups each day, which could be distributed in any combination between the two levers. Under baseline experimental conditions each subject was allotted 300 lever presses, resulting in the budget set represented by the shaded area bounded by the straight line A in Figure 1.

FIGURE 1



Changing the total number of lever presses allotted, holding cup size and lever pressing requirements constant, would result in a shifting out or in of the boundary of the budget set parallel to itself; e.g., increasing lever presses allotted to 400, holding other conditions constant, would result in an expansion of the budget set in Figure 1 to include the area bounded by the straight line A'. Thus, under the experimental procedures adopted,

the total number of lever presses allotted corresponds to the concept of income in the definition of the budget set and will be referred to as such. Changing dipper feeder cup sizes while maintaining one dipper presentation per lever press would result in altering the slope of the budget line; e.g., holding total lever presses set at 300 while increasing the Collins mix dipper cup size to .1 ml and reducing the root beer cup size to .025 ml would result in the choice set bounded by the straight line A'' in Figure 1.[1] Maintaining the requirement of one dipper press per presentation, the number of lever presses required to obtain 1 ml of either commodity corresponds to the concept of price in the definition of the budget set and will be referred to as such.[2]

Throughout the experiment the subjects remained in the experimental chamber continuously, 7 days a week, except for a period each morning when the cage was cleaned, commodities were replenished, the income allottment was reset, and the data were recorded. Each experimental condition (constant set of prices and income) was maintained for a minimum of 14 days. In addition, a stability criteria of 10 consecutive days, during which no trend was observed in either consumption patterns or time taken to exhaust income, had to be met before conditions were changed. Unless noted otherwise, data are reported for all but the first three days of an experimental condition.

Results and Discussion

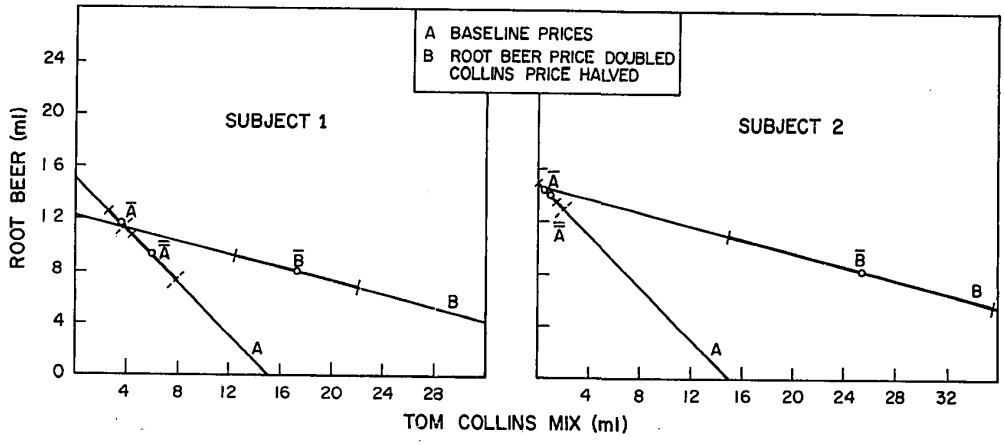
The budget line under baseline experimental conditions is represented by the straight line A in Figure 2. Mean daily consumption, or purchase, is designated by the point $\bar{A}$ and the brackets indicate ± one standard deviation of the observations about the mean. At this income level, with the prices of the goods the same, both subjects consumed a commodity bundle containing substantially more root beer than Collins mix. To test for the consistency of purchase patterns with the Slutsky-Hicks theory, following Condition (1), we doubled the price of root beer, halved the price of Collins mix, and adjusted total income so that the new budget line passed through $\bar{A}$. This new budget line and mean daily purchases of

1. The amount of time each cup remained available was changed proportionately with the cup size in all cases.

2. Root beer and Collins mix were chosen on the basis of a pilot study that showed that when either root beer or Collins mix and water were simultaneously available most rats studied drank these two fluids in preference to water. In conducting the experiments reported here, one subject was found who did not drink Collins mix when water was freely available. In view of the experimental problem under study, namely the changes in root beer and Collins mix consumption that result from changes in the price of these commodities when water is freely available, this subject was excluded (Sidowski and Lockard, 1966, pp. 21-22).

root beer and Collins mix are shown in Figure 2 as the straight-line B and point $\bar{B}$ respectively, where the brackets again indicate the standard deviation of the observations about the mean. For both subjects this change in the budget set resulted in a substantial change in consumption patterns with each subject increasing the consumption of Collins mix and reducing the consumption of root beer.[3] These changes were sufficiently great in both cases that the subjects consumed more Collins mix than root beer.

FIGURE 2



The variability of daily purchases reported in Figure 2 under a constant set of prices and income is explained, in part, in terms of uncontrolled changes in the subject's environment. Even with the most rigorous control of experimental conditions, the subject is continuously exposed to changes in environmental conditions. At the very minimum these will be confined to changes that occur as a result of its own behavior as well as variations in such factors as temperature, humidity, variability in the composition of commodities, sexual cycles, etc.[4] In view of these considerations we decided to use the value for mean purchases in determining whether con-

3. In addition to the changes in purchase patterns, the price changes also resulted in large decreases in water intake from an average of 13.6 and 24.4 ml to 4.4 and 11 ml for subjects 1 and 2, respectively, and a sharp increase in the time taken to exhaust the income allocation from an average of 427 and 278 minutes to 875 and 1029 minutes for subjects 1 and 2, respectively.

4. Whether the degree of control of behavior in any particular experiment is acceptable can only be answered in terms of the questions the experiment is designed to investigate. When the variation in the variables being studied is small under constant experimental conditions relative to the changes in behavior resulting from changes in experimental conditions, as in the present studies, then an acceptable degree of control has been attained (Sidman, 1960). This does not preclude conducting studies at a later time designed to identify exactly what factors are affecting the variability in purchase patterns under constant experimental conditions.

sumption patterns satisfied Condition (1) above. Given the large differences in mean values between experimental periods relative to the variation in observations within each experimental period, we have interpreted the data as being consistent with the Slutsky-Hicks theory.[5]

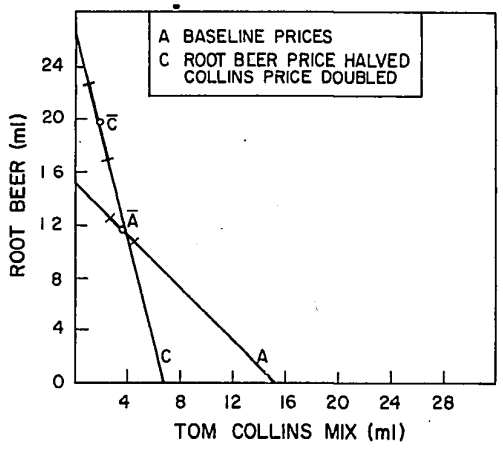
Returning prices and income to baseline conditions resulted in an immediate and sharp reversal of purchase patterns towards the original baseline values. Mean purchases and standard deviations are represented in Figure 2 by the point $\bar{A}$ and the brackets extending in both directions. For subject 1, mean purchases failed to completely return to their original values. This subject consumed more Collins mix and less root beer than in the original baseline period. While mean purchases of subject 2 were virtually the same under baseline conditions before and after the price changes, during the first two weeks following the return to baseline conditions average Collins mix consumption was some four times larger than for the last 10 days of the original baseline period (1.5 ml *vs.* .4 ml). The relatively high average value over these two weeks resulted from a number of relatively high Collins mix consumption days spaced between days of little or no Collins mix consumption. The substantially lower average Collins mix consumption for the whole period (.88 ml) results from a sustained period of low Collins mix consumption at the end of the period. In contrast, purchase patterns for subject 1 showed no tendency to return to their original values and on only one day did the purchases of Collins mix fall below the mean value reported during baseline.

As a further test of the consistency of purchase patterns with the Slutsky-Hicks theory, we doubled the price of Collins mix and halved the price of root beer for subject 1, adjusting income so that the budget line again passed through $\bar{A}$. This new budget line is represented by the straight line C in Figure 3, and mean consumption of root beer and Collins mix is shown as point $\bar{C}$. Once again the subject's response to the price changes was to consume less of the higher priced fluid and more of the lower priced fluid than under baseline conditions, which is consistent with Condition (1).[6]

5. Characterizing the rats' purchases as a random variable with a normal distribution over the budget line, the probability is less than .05 that mean purchases under budget line B lie to the left of point $\bar{A}$ for both subjects. Using these same premises, the other checks of the consistency of mean purchases with Condition (1) reported in the text were all significant at the 5% confidence level.

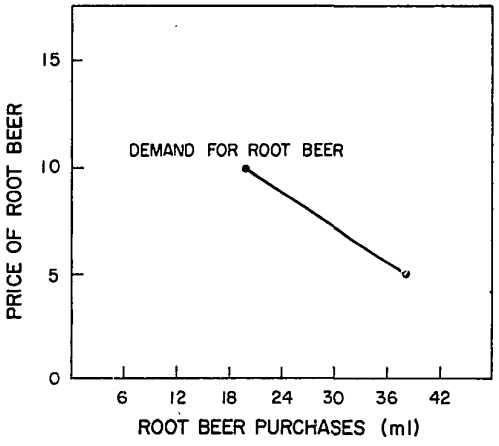
6. Interestingly enough, in this case the amount of water consumed increased to about 16.7 ml and the time taken to use the budget allocation dropped even though consumption of root beer and Collins mix increased some 33% over baseline.

FIGURE 3



Having established that the behavior of subject 1 was consistent with Condition (1), we further reduced the price of root beer, holding income and the price of Collins mix constant, to determine whether the demand curve for root beer was negatively sloped. As shown in Figure 4, this price reduction resulted in substantially increased root beer purchases.[7] The arc elasticity of demand for root beer, calculated from the mean quantity data reported in Figure 4, is about -1.0.

FIGURE 4



7. With this further increase in root beer consumption, water intake decreased to about 4.8 ml and time spent in using up income increased to an average of 704 minutes. The rather large increases in total fluid consumption reported here and under budget line *C* is not atypical. An independent series of experiments in which rats were given a 1 hour access to a highly preferred fluid showed that they generally drank large amounts of the preferred fluid during this 1 hour while decreasing their water consumption only slightly during the other 23 hours spent in their home cages [Ernits, 1973 and personal correspondence with Professor Ernits].

As a demonstration of the degree of control of the experimental variables (prices and income) and commodity preferences on behavior, two additional studies were performed. To demonstrate that, under a given set of prices and income, purchase patterns resulted from preferences for root beer and Collins mix rather than preference for pressing one lever over the other, we switched the levers producing root beer and Collins mix for subject 1 holding prices and income constant at baseline values. As the data in Table 1 indicate, there were no significant differences in purchase patterns associated with the levers producing the commodities.[8]

Table 1

Test for Lever Bias: Subject 1

Experimental Conditions		Root Beer Consumption		Collins Mix Consumption	
Left Lever	Right Lever	Mean	Standard Deviation	Mean	Standard Deviation
Collins mix	Root Beer	11.77	1.6	3.23	1.6
Root Beer	Collins mix	11.77	1.3	3.23	1.3

In the second study, using subject 2, we put root beer in both dipper feeders and placed a larger cup on one of the dipper feeders. In the absence of lever bias, and in the presence of an effective budget constraint, this should, according to the Slutsky-Hicks theory, result in purchases being confined to the lever with the larger cup size. As the data in Table 2 show, with the larger dipper cup on the left than on the right, consumption was almost exclusively confined to the left lever. Further, switching dipper cups so that the lower price prevailed on the right lever and the higher price was on the left lever resulted in an immediate and complete switching of consumption from the left to the right.

8. The data reported in Table 1 are from two experimental periods of 26 and 22 days respectively that sequentially followed the return to baseline conditions reported in Figure 2. We note that the sharp change in experimental contingencies involved in switching levers resulted in elimination of the residual effects of the price contingencies of budget line *B* on consumption patterns noted in the text.

Table 2

Root Beer Consumption with Root Beer Behind Both Levers: Subject 2

Price of Root Beer[1]		Percent of Total Consumption[2]			
Left Lever	Right Lever	Left Lever		Right Lever	
		Mean	Range	Mean	Range
10	40	.992	.998-.987	.008	.013-.002
40	10	.006	.013-.002	.994	.998-.987

[1] Prices expressed in terms of lever presses per .1 ml of root beer.

[2] To indicate the immediacy of response to the price changes, data are reported for last 5 days of the first period and the first 5 days of the last period.

II. FOOD – WATER EXPERIMENT

Subjects

Two white male albino rats, both of the Sprague-Dawley stock were used. Both subjects were between 90 and 120 days of age at the beginning of the experiment and had no previous experimental history.

Apparatus

The food-water experiment used similar apparatus to that reported above for the root beer-Collins mix studies with the difference being that a food pellet dispenser was behind the left lever. Presses on the left lever caused a predetermined number of 45 mg Noyes food pellets to appear in a recessed food tray located at floor level directly below the lever, whereas presses on the right lever resulted in delivery of water from a dipper feeder mechanism. The pellets remained in the food tray until consumed.

Procedure

Ten presses on the left lever were required for each delivery of food pellets, and ten presses on the right lever were required for each presentation of water from the dipper feeder. The subject's income was interpreted as the limited sum of total presses available each day. The requirement of 10 lever presses for each delivery of food and water, given the magnitude of the commodities actually delivered as well as the total lever pressing

requirement imposed by the income levels employed, was small relative to the magnitude of lever pressing rats can perform in experimental chambers (Collier, Hirsch and Hamlin, 1972). Relative prices were changed by adjusting the number of pellets delivered, maintaining ten presses per delivery on both levers and maintaining a constant cup size on the water dipper feeder. Each subject was free to distribute its total presses in any way between the two levers. The subjects had no other access to food or fluid.

Subject 1 was initially shaped to press 20 times for 5 pellets of food and a like number of times for .1 ml of water. These lever pressing requirements were maintained for an initial 5 week period during which income was set at 4,000 lever presses followed by another 5 week period during which income was set at 5,000 bar presses. For the baseline period reported on below, these requirements were reduced to 10 lever presses for 5 pellets of food and 10 lever presses for .1 ml of water with income set at 2,500 lever presses. As the data shown in Table 3 indicate, the average amounts of food and water consumed and the total time spent in using up the budget allocation showed little change in response to these changes in prices and income, indicating that the underlying demand functions for food and water were homogeneous of degree zero for a proportionate decrease in prices and money income.

Table 3

Homogeneity of Demand Behavior With Respect to Decreases in Prices and Money Income: Subject 1

Experimental Conditions			Consumption				Time	
Prices[1]		Income	Food (grams)		Water (ml)		(minutes)	
Food	Water		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
88.9	200	5000	17.1	2.1	17.4	.9	181	58
44.4	100	2500	17.5	2.1	17.2	.9	218	47

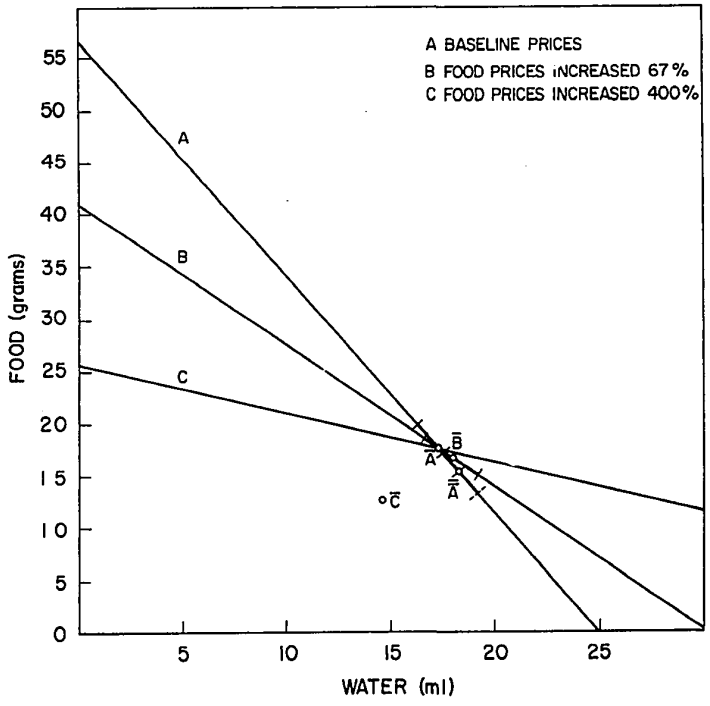
[1] Prices expressed in terms of lever presses per gram of food and ml of water.

Results and Discussion

The budget line under baseline experimental conditions for subject 1 is represented by the straight line A in Figure 5. Mean daily purchases are designated by the point $\bar{A}$ and the brackets indicate the standard devia-

tions. This diet was sufficient for nominal increases in weight but was insufficient for the subject to attain normal body weight over the course of the experiment. To test for the consistency of consumer purchase patterns with the Slutsky-Hicks theory we increased the price of food 67% (10 lever presses for 3 pellets of food) and simultaneously increased income so that the same amounts of food and water could be purchased as under baseline conditions. This new budget line is represented by line B in Figure 5 and mean purchases are represented by the point $\bar{B}$. The response to this change in relative prices, while far less than in the root beer-Collins mix studies, still resulted in some small alteration of the composition of consumption in favor of the cheaper water and away from the more expensive food.[9] This change in the composition of consumption was greatest in the period immediately following the price change and remained essentially unchanged for about three weeks. However, following this, consumption patterns started to drift towards baseline values over the next two weeks. We then introduced a further price increase in food to determine if we could induce further changes in the composition of consumption.

FIGURE 5



9. We need a dimension free measure of changes in consumption to make this comparison between experiments. Since the observations consist of points on a demand curve with apparent real income held constant, we compared the arc elasticities of the mean consumption data.

The price of food was increased 400% over baseline (10 lever presses for 1 pellet) while income was simultaneously increased so that the baseline consumption bundle could continue to be purchased (budget line C in Figure 5). This change not only induced a further decrease in the ratio of food to water purchases, but also resulted in the subject spending an average of only 76.2% of its total income allowance in the 24 hours allotted. This suppressed responding was immediate and continued for the entire experimental period, which was limited to 17 days, as the subject steadily lost weight. Mean purchases for this period are shown as point $\bar{C}$ in Figure 5.

Returning economic conditions to baseline values (budget line A) eliminated the suppressed responding. However, the subject remained on a weight loss trend, with water consumption higher and food consumption lower than under the original baseline conditions, and steadily increased the time used to spend all its income to over 22 hours. The introduction of a 14 day experimental period during which the price of food was halved again (10 lever presses for 10 pellets of food) resulted in a reversal of the weight loss trend and a reduction in time taken to spend all the income to about 5 hours. A return to baseline conditions following this resulted in continued weight gain, a time spent consuming of about 8 hours (still double the time spent originally) and continued alteration in the composition of consumption relative to baseline away from food and towards water (point $\bar{\bar{A}}$ in Figure 5). A return to budget line C at this point reproduced the original behavior with the subject spending less than its total income and again losing weight.

The suppressed responding of this subject, who weighed only about 80% of normal body weight, cannot be directly attributed to the total number of lever presses required to obtain food and water since under budget line C average total presses remained consistently below 5,000 per day, a number that the same subject had consistently performed within a period of 3-4 hours during the 5 week pre-baseline period (see Table 3 above). To further study this behavior we placed an experimentally naive subject under the price and income contingencies (budget line C) associated with the failure of the first subject to finish. This second subject used its entire income under budget line C. However, when this second subject was exposed to budget line A for six weeks and then returned to budget line C it too failed to spend all its income. In this case the suppressed responding did not occur immediately with the return to budget line C, but abruptly followed a 19-day period during which spending patterns, as well as the time spent consuming, were quite similar to the behavior reported initially under budget line C. After 7 days of suppressed responding under budget line C, during which the subject averaged 61%

of total lever presses allotted and rapidly lost weight, restoring budget line A resulted in the subject once again spending all its income. However, similar to the first subject, the period of suppressed responding left marked residual effects on behavior. The time spent consuming increased, food purchases sharply decreased as compared to previous behavior under budget line A, and the subject continued to lose weight.

The results from this second subject provide further evidence that the suppressed responding of the first subject did not result from the contingencies of budget line C itself. Rather, the data from the second subject indicate that the severe disruption of behavior reported for both subjects resulted from the sharp increase in the relative price of food represented by the rotation of the budget line from A to C.

III. DISCUSSION

In presenting the results of our experiments to colleagues several general questions concerning the procedures and methods used have been raised. One question frequently raised is that, since rats must lever press in order to consume, our experimental procedures include a work component and this may be responsible for the behavior reported. In response to this we note that all observed purchasing and consumption behavior are activities that by their very nature require energy expenditure or work. Indeed, economic theorists have recently suggested that the traditional distinction between work and consumption is, at best, imprecise since both activities involve combining material resources, energy expenditure and time in the production of commodities (see Becker, 1965, for example). We recognize that alternative methods of changing the budget set (interpreting prices and income) may give different results from those reported here. Whether this is the case or not is an empirical issue that can only be settled by conducting further experiments. However, irrespective of the outcomes of these experiments, the observations reported from the present studies will remain unchanged. Rather, our interpretation of the results of the experiments may need to be modified.[10]

A second issue frequently raised concerns the small number of experimental subjects used. We interpret this remark to mean how, with so few subjects, we can be sure that it was the changes in economic parameters

10. Experiments are currently underway to explore this. In one of these studies the lever pressing requirement is eliminated entirely. In an earlier, as yet unpublished, food-water study, we adjusted prices by simultaneously altering the magnitude of payoff and lever pressing requirements. Similar to the data reported here between budget lines A and B, the purchase patterns of this subject were consistent with the Slutsky-Hicks theory and the substitution terms of the underlying system of demand functions were close to zero.

that affected behavior rather than uncontrolled (experimental "noise") factors or idiosyncracies of our experimental methods or subjects. The answer is, of course, that we can never be sure, nor do we assert that we are sure, that our results will be reproducible by other experimenters (or even ourselves) using more or less similar experimental procedures.[11] Rather, the individual research decision that must be made is when to stop directly replicating results and reallocate the limited resources to the investigation of new and related questions. Since modern logic provides no guidelines with respect to making such a decision, all we can do is indicate the pragmatic considerations involved in our decision. First, under the *ABA* (baseline–experimental conditions–baseline) experimental design used, which allows each subject to serve as its own control, the reversibility of behavior with the return of economic parameters to baseline values following the changes in experimental conditions provides strong evidence that it was the changes in experimental conditions, rather than some other uncontrolled or fortuitous circumstance, that was responsible for the changes in consumption reported. Second, we have replicated the behaviors reported across different subjects (intersubject replication), and, in the case of the root beer-Collins mix experiment, this was done by different researchers in different laboratories. Further, we have replicated the behaviors reported over the same subject (intrasubject replication); e.g., for subject 1 in the root beer-Collins mix experiment we first doubled the price of root beer and halved the price of Collins mix and then doubled the price of Collins mix while halving the price of root beer recording a symmetric alteration in consumption patterns in both cases. Finally, each experimental condition (set of prices and income) was maintained for a minimum of 14 days and conditions were only changed when a subject repeatedly displayed similar responses to the same set of economic contingencies.

Our experiments have shown that laboratory animals will change consumption patterns in response to changes in the budget set, consuming less of higher priced commodities and more of lower priced commodities. The consistency of purchase patterns of the subjects in the root beer-Collins mix experiment with Condition (1) indicates that their consumption behavior can be characterized by members of the class of Slutsky-Hicks demand functions. The failure of the purchase patterns of these subjects to immediately return to baseline values once they had been displaced replicates behavior reported in an earlier experiment involving human subjects in a token economy (Battalio, Kagel, Winkler, et al., 1973, 1974). As

11. The material in the book by M. Sidman (1960) contains a substantially more detailed discussion of the considerations involved in the design of laboratory experiments and the evaluation of the outcomes of such experiments.

with the human subjects, the differences in these residual effects between subjects and a determination of the permanancy of these effects remains unexplained. However, the experimental methods developed here are ideally suited to answering such questions and to studying the basic mechanisms underlying the phenomena reported.

The suppressed responding and weight losses reported in the food-water experiment in the face of changes in the budget set are not characterizable in terms of the Slutsky-Hicks theory as presently formulated. The severe disruption in behavior we have shown to be the result of the rotation of the budget line resulting from the large increase in the relative price of food, rather than a function of the contingencies of the budget set itself. We do not know the reason for this behavior at the present time. It could be due to any number or combination of factors such as the commodities over which the budget set was defined, the extremely large changes in relative prices involved, the method by which relative prices were changed, the subjects initial income level, etc. Determining what the relevant factors are will require further experiments.

Since the experimentally induced changes in the budget set in the root beer-Collins mix experiment and the small changes in the budget set in the food-water experiment resulted in changes in consumption patterns quite similar to those reported for individual human consumers (Battalio, Kagel, Winkler, et al., 1973, 1974), the question arises as to whether changes in the budget sets of human consumers may also be associated with disruptive behavior. Although we do not have any direct empirical data at present, there is a substantial body of literature in psychology and sociology relating severe disruptions of human behavior, i.e., suicides and mental disorders, to socio-economic factors such as poverty and unemployment.[12] While it is clear that suppressed responding and weight losses in rats are not the same thing as suicides and mental disorders in humans, this literature does indicate that severe disruptions in human behavior are associated with economic factors. This suggests that in experimental studies of consumer behavior using human consumers the experimenter must guard against changes in the budget set that may result in severe disruptions of the consumers behavior and must be prepared to alter the experimental design accordingly. Further, experimental studies designed to determine the precise factors underlying the disruptions in behavior reported here must be limited to laboratory animals on both ethical and legal grounds. The generality of this behavioral process to human con-

12. Two of the most important studies in this area are the books by Brenner (1973) and Henry and Short (1954). This research is, of course, not without its critics (see Douglas, 1967; Mishler and Scotch, 1963). Economists have generally tended to ignore these relationships in their analysis of behavior (see Hamermesh and Soss, 1974, for an exception to this generality).

sumers can then be determined by applying the information gained from the animal studies to the design of permissible experiments with humans.

In the experiments reported we have extended the technology developed by operant psychologists to the study of consumer demand behavior of laboratory animals and have shown important similarities in the behavioral processes associated with changing budget sets between these animals and human consumers. This technology can be adapted to study wide classes of behavioral processes of interest to economists (Kagel and Winkler, 1972). While psychologists have, on occasion, adventitiously applied this technology to the study of problems directly of interest to economists (see for example Rachlin and Green, 1972) the application of this technology to the direct study of economic behavior will require major adaptations in the experimental procedures, designs, and concepts commonly employed in experimental psychology. Adapting this technology to the study of economic behavior promises to open exciting new areas of empirical research in both economics and behavioral psychology.

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