DOES PACKAGE SIZE MATTER? A UNIT-PRICE ANALYSIS OF "DEMAND" FOR FOOD IN BABOONS

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In a study examining "demand" for food, responding of 8 adult male baboons (*Papio c. anubis*) was maintained under a fixed-ratio schedule of food reinforcement during daily 23-hr experimental sessions. Completion of the ratio requirement resulted in the delivery of one, five, or 10 1-g food pellets. Supplemental feeding was limited to fruit and a dog biscuit daily. Responding increased as "cost" was increased across a wide range of fixed-ratio values before reaching a maximum and then decreasing. Increasing the number of food pellets per delivery decreased total responding and the number of reinforcements per day. A unit-price analysis, in which intake was converted to grams per day and fixed-ratio values were converted to responses per gram, yielded demand functions that overlapped at lower unit prices. Under one or more multiple-pellet conditions, however, intake decreased more quickly than under the one-pellet condition as the fixed-ratio value was increased in all but 1 baboon. This indicates that even when using unit-price conversions, there was variability in total intake. Although unit-price conversions yielded intake data that were more consistent across conditions, conditions differed in response topography even at the same unit prices: Under the multiple-pellet conditions there were longer pauses in responding, running response rate was slower, and the first eating bout (i.e., "meal") of the session was smaller than under the one-pellet condition. These findings (a) support the heuristic value of a unit-price analysis for studying responding for and consumption of commodities that have similar attributes, and (b) indicate that different response topographies may result in similar intakes of a commodity.

Key words: behavioral economics, demand, food intake, fixed-ratio schedule, lever pull, unit price, baboon

The recent application of economic principles to the experimental analysis of behavior has provided a substantial impetus in the search for common behavioral mechanisms across a range of environmental conditions (Allison, 1981, 1983; Hursh, 1980, 1984; Hursh & Bauman, 1987; Lea, 1978). Economic models emphasize the importance of studying responding maintained by a commodity at more than one response requirement, or cost. Responding initially increases with small increases in cost, maintaining stable levels of intake. As cost continues to increase, responding eventually reaches a maximal amount, and intake correspondingly begins to decrease. When cost reaches a certain value, responding then decreases and intake decreases dramatically. When responding and intake are measured as a function of increasing cost, it is

possible to describe changes in value of a reinforcer in more general "demand" terms.

Comparisons among different commodities can be readily made by comparing demand functions. Hursh (1980) suggested that when commodities have something in common, this commonality should be used to arrive at the underlying demand structure. For example, when comparing responding maintained by different masses of the same food, the food mass should be incorporated in the analysis. In that case, price should be summarized as "unit cost per gram" and intake summarized as "grams of food per day." In a study on food intake in rats, three originally disparate demand curves generated by different-sized food pellets nearly overlapped when food intake and cost were converted to common units. The utility of such "unit-price" analyses when studying responding by rats maintained by different-sized pellets has been confirmed by Collier, Johnson, Hill, and Kaufman (1986).

The unit-price concept was formalized by Hursh, Raslear, Shurtleff, Bauman, and Simmons (1988) with the following definition:

$$\text{Unit price} = \frac{\text{responses} \times \text{effort}}{\text{reinforcers} \times \text{value}}$$

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Values in the numerator describe the work required to obtain reinforcement: Responses indicate the number of lever operations, and effort indicates other factors relating to the difficulty of responding (e.g., duration of the lever press, force required to deflect the lever, etc.). Values in the denominator describe reinforcer packages: Reinforcers indicate the number of reinforcers delivered, and value describes physical attributes of the reinforcer (e.g., weight, caloric concentration, flavor, etc.). For example, Hursh et al. manipulated the numerator of the equation by altering the force required for rats to complete a lever press. The denominator was altered by varying the number of pellets per delivery. A wide range of conditions was tested to evaluate the utility of a unit-price analysis. Although there were some conditions that deviated from others when analyzed as a function of unit price, the analysis was generally useful in accounting for the variance in the observations. Others have been applying unit-price analyses to situations involving drug self-administration by rats, humans, and nonhuman primates (Allison, 1979; Bickel, DeGrandpre, Higgins, & Hughes, 1990; Bickel, DeGrandpre, Hughes, & Higgins, 1991; DeGrandpre, Bickel, Hughes, & Higgins, 1992). Their studies and reanalyses of published data indicate that the unit-price concept has utility for understanding behavior in species other than rats and with reinforcers other than food.

In a recent paper, Foltin (1992) examined the responding of baboons maintained by packages of 1, 5, or 10 g of food across a limited range of fixed-ratio values. Although the study was not designed to test a unit-price hypothesis, the data suggested that there were deviations from the unit-price prediction in the multiple-pellet conditions. The results suggested that there may be an interaction between package size (i.e., the number of 1-g pellets per food delivery) and cost, because converting intake to grams per day and cost to responses per gram did not result in overlapping demand curves. Unfortunately, the range of fixed-ratio values was limited such that it was not possible to examine the unit-price concept properly. The purpose of the present experiment was to determine the possible interaction between the magnitude of reinforcement and response requirements in baboons using a unit-price analysis and to provide an analysis

of response topography at similar unit prices with different package sizes.

METHOD

Animals and Apparatus

Eight adult male baboons (*Papio cynocephalus anubis*), weighing 23.4 to 48.3 kg, were housed in standard primate cages (0.94 m by 1.21 m by 1.52 m high) at The New York State Psychiatric Institute. The baboons had 6 months' to 3 years' experience responding under fixed-ratio schedules of food delivery. Six of the baboons had participated in an earlier study in which the number of pellets per food delivery was manipulated (Foltin, 1992). The room was illuminated with fluorescent lighting from 6:00 a.m. to 6:00 p.m. daily. In addition to food earned during experimental sessions, chewable vitamins, two pieces of fresh fruit (80 to 100 kcal each), and a dog biscuit (150 kcal) were also given daily. Water was available ad libitum. A panel holding a food hopper, two Lindsley levers (Gerbrands), four stimulus lights (two above each lever), and a pellet dispenser (BRS-LVE Model PDC-005) was attached to the front of each cage. All schedule contingencies were programmed using Apple® IIgs computers located in an adjacent room.

Procedure

Responding on the lever to the baboon's right was maintained by food delivery (Formula L® Noyes banana-flavored 1-g food pellets containing 3.7 kcal/g: 21.0% protein, 4.7% fat, 62.0% carbohydrate, 5.3% ash, 3.1% moisture and 3.0% fiber) under a fixed-ratio (FR) schedule. Under the FR schedule, a reinforcer was delivered upon completion of a set number of responses (i.e., lever pulls). The response requirement was changed by increasing or decreasing the number of responses required for reinforcer delivery. A 30-s timeout followed each pellet delivery. Responding during this 30-s intertrial interval (ITI) was recorded but had no programmed consequences. The baboons could initiate responding at any time. The first response of a new FR started a limited-hold timer: If the response requirement was not completed within the limited-hold period, which varied with the response requirement (limited hold = FR value $\times$ 10 s), the 30-s ITI was initiated and the ratio was reset.

The schedule was in effect 23 hr per day, 7 days per week, from 10:00 a.m. to 9:00 a.m. the following morning. The remaining hour of the day was used for cage and animal maintenance. Illumination of the red stimulus light above the right lever indicated the availability of food. After the first response, the limited-hold timer began, the red light above the lever was extinguished, and a green stimulus light was illuminated above the same lever. During the timeout and cage maintenance periods, no stimuli were illuminated. Responses on the left lever had no programmed consequences and were not recorded.

Initially, the FR requirement was two responses resulting in the delivery of one food pellet. The response requirement was increased, usually by doubling the ratio, on Mondays, Wednesdays, and Fridays until the total daily food intake decreased to about 150 g. Thus each cost was in effect for 2 or 3 days under each condition. Response costs were changed on these 3 days each week, rather than every other day, to minimize the possibility of protocol error. Because the FR values were increased until daily food intake decreased to about 100 to 150 pellets, the ratio requirements varied among the baboons. The final FR value under the one-pellet-per-FR conditions was 48 for Baboons 1, 2, and 3 (Group 1) and was 128 for the remaining 5 baboons (Group 2). For half of the baboons, the minimal response requirement was increased to 10 and the number of pellets delivered following completion of each FR was increased to five. For the remaining baboons, the minimal response requirement was increased to 20 and the number of pellets delivered following completion of the FR was increased to 10. The response requirement for five pellets was increased from 10 to a maximum of 160 for the baboons in Group 1 and 280 for the baboons in Group 2. The response requirement for 10 pellets was increased from 20 to a maximum of 240 for the baboons in Group 1 and 400 for the baboons in Group 2. After responding under the largest FR value was tested, the response cost was again reduced to the minimum for the number of pellets that were being delivered. The 4 baboons that had been obtaining five pellets per delivery (1, 5, 7, and 8) were then tested with the conditions appropriate for 10 pellets per delivery, and the 4 baboons (2, 3, 4, and 6) that were obtaining

10 pellets per delivery were then tested with the conditions appropriate for five pellets. The number of pellets per delivery was then returned to one, and the effects of increasing the responses per pellet delivery were redetermined twice. The Appendix contains the unit prices that were tested for each baboon under each condition.

Data Analysis

Data collected on the 2nd day of each FR condition (3rd day if the FR was changed on Friday) were included in the analysis. Responding and reinforcement were recorded throughout the day, providing the following dependent measures: cumulative intake throughout the day; running rate (responses per second); mean pause length between reinforcement and initiation of the next FR (minimum of 30 s due to the ITI); number of responses emitted during ITIs; number of started ratios that were not completed during the limited hold; and size and running rate of responding during the first meal of the day (the first meal was defined as beginning with the first response of the session and ending when there was a pause of greater than 10 min between reinforcement and initiation of responding under another FR).

Data were analyzed using a unit-price conversion, which summarized responding as cost per unit of the reinforcer (in the present case responses per gram). To determine unit price under the five-pellet condition, intake under each cost was calculated by multiplying the number of reinforcer deliveries by five, and cost per gram was determined by dividing the FR value by five. Thus, obtaining five pellets under the FR 10 schedule was equivalent to obtaining one pellet under the FR 2 schedule (i.e., $10 \text{ responses}/5 \text{ g} = \text{two responses}/1 \text{ g}$), obtaining five pellets under the FR 20 schedule was equivalent to obtaining one pellet under the FR 4 schedule, and so on. Unit price under the 10-pellet condition was determined by multiplying the number of reinforcers by 10 and dividing the FR value by 10 (e.g., $20 \text{ responses}/10 \text{ g} = \text{two responses}/1 \text{ g}$). Unit prices of 2, 8, 16, and 32 responses per gram under the one-pellet condition and 2, 8, 16, and 24 responses per gram under the multiple-pellet conditions were used in the analyses for Group 1. Unit prices of 2, 16, 32, 64, and 128 responses per gram under the one-pellet condi-

tion and 2, 8, 16, 32, and 40 responses per gram under the multiple-pellet conditions were used in the analyses for Group 2. Data obtained under the three one-pellet conditions were combined to provide means for graphing and summarizing intake under the one-pellet condition.

RESULTS

For each dependent measure, data from 1 baboon in each group will be presented along with the group-mean data, graphed separately for the two groups of baboons. Figure 1 presents food intake (in grams) graphed as a function of unit price (i.e., number of responses emitted to obtain 1 g of food). Increasing the unit price from 2 to 32 responses per gram under the one-pellet condition decreased pellet intake by about 50% for Baboons 1, 2, and 3, whereas increasing the unit price from 2 to 128 responses per gram under the one-pellet condition decreased pellet intake by about 75% for Baboons 4 through 8. When expressed as a function of unit price, intake at the lower costs under the multiple-pellet conditions substantially overlapped mean intake under the three determinations of the one-pellet condition. Thus, when food was available at a unit price of two responses per gram, increasing the number of pellets per delivery produced no consistent alteration in daily food intake compared to the one-pellet condition: Total daily food intake under the five-pellet condition was similar ($\pm 10\%$) to the one-pellet condition in 5 baboons, greater in 2 baboons, and lower in 1 baboon; total daily food intake under the 10-pellet condition was similar to the one-pellet condition in 4 baboons, greater in 1 baboon, and lower in 3 baboons.

The unit-price analysis revealed an unexpected finding in that for all baboons except Baboon 6, food intake under one or both of the multiple-pellet conditions decreased more rapidly as unit price increased than it did under the one-pellet condition. This pattern is clearly shown by the individual-subject data presented in the top panels of Figure 1. The group means, presented in the bottom panels of Figure 1, indicate that this effect was most evident for the baboons in Group 1. Although the baboons had long histories of responding under ratio schedules, they had no experience with the larger FR values used under the mul-

ti-ple-pellet conditions. It is possible that the more rapid decrease in food intake under multiple-pellet conditions was associated with the initial exposure to large FR values; this was not consistently the case. Although for 3 baboons the decrease was associated with the first multiple-pellet condition, for 2 baboons the decrease was associated with both multiple-pellet conditions, and for 2 baboons the decrease was associated with the second multiple-pellet condition.

Figure 2 presents cumulative pellet intake as a function of session time for 1 baboon from each group. The first one-pellet condition was compared to the 10-pellet condition under two unit prices. For all baboons under the same unit prices, responding under the multiple-pellet conditions was characterized by longer pauses between reinforcer delivery and the initiation of another FR. This is evident by the jagged appearance of the cumulative intake curves in the right panels of Figure 2. The majority of responding occurred when the room was illuminated. The daily cumulative intake curves contain the "break-and-run" patterns characteristic of FR responding.

The top panels of Figure 3 present the mean pause between reinforcer delivery and the initiation of another FR as a function of unit price and pellet condition. Under the one-pellet condition, increasing the cost of food increased the mean pause from about 3 min under the lowest cost to 10 min under the highest cost for both groups of baboons. Increasing the number of pellets per delivery produced parallel upward pellet-dependent shifts in pause length. This shift was almost perfectly arithmetic, such that baboons paused 3 min for each pellet delivered when the unit price was two responses per gram. The bottom panels of Figure 3 present mean running rate as a function of unit price and pellet condition. Baboons responded at a consistently higher rate under the one-pellet condition compared to the multiple-pellet conditions. Running response rate was also minimally affected by unit price; it was generally consistent within conditions at all unit prices. An apparent exception to this finding is the larger running rate when one pellet was delivered at minimal cost. This value is inflated due to the fact that it is based on the interval between two responses, which was occasionally as short as 0.10 s, giving running rates of 10 responses per second. Increasing

23-Hr Intake

Fig. 1. Total 23-hr intake (grams per day) as a function of unit price (responses per gram) under the one-pellet condition (mean of three determinations) and both multiple-pellet conditions. The top panels present data from a representative from each group of baboons; the bottom panels present the mean data for each group. Error bars represent 1 SEM. Note that axes are logarithmic and that x axes differ for the two groups.

the number of pellets per delivery had minimal effects on the number of pellets delivered under low cost conditions, but this increase altered response topography such that baboons had longer pauses between bouts of responding and responded at lower response rates under the multiple-pellet conditions.

The top panels of Figure 4 present the mean number of times that a baboon initiated responding but failed to complete the FR requirement as a function of unit price and pellet condition. Once a baboon initiated a bout of responding, it was rare that the baboon did not complete the ratio, regardless of the unit price and the number of pellets per delivery. Under most unit prices, the number of incompletes varied between only one and five

per day. Thus, when responding resumed after a pause, it continued at a consistent rate until reinforcement occurred. The bottom panels of Figure 4 present the mean total number of responses emitted by each baboon during the 30-s ITI as a function of unit price and pellet condition. Baboons emitted five to 10 times more responses during the ITI under the one-pellet condition than under the multiple-pellet conditions. Also, as the unit price increased, responding during the ITI decreased. This differential amount of ITI responding is due to the five to 10 times larger number of reinforcer deliveries and ITIs under the one-pellet condition than under the multiple-pellet conditions. Dividing the number of ITI responses by the number of reinforcer deliveries under

Fig. 2. Cumulative pellet intake in grams for a representative baboon from Group 1 (top four panels) and Group 2 (bottom four panels) obtained under the initial one-pellet condition and the 10-pellet condition at the lowest and highest unit price that both conditions had in common. Each symbol represents reinforcement, not a response.

Fig. 3. Mean pause between reinforcement and the initiation of another FR (top panels) and mean running response rate (bottom panels) as a function of unit price (responses per gram) under the one-pellet condition (mean of three determinations) and both multiple-pellet conditions. See Figure 1 for details.

Fig. 4. Mean number of incomplete ratios (top panels) and mean number of ITI responses (bottom panels) as a function of unit price (responses per gram) under the one-pellet condition (mean of three determinations) and both multiple-pellet conditions. See Figure 1 for details.

each condition minimizes differences among the three conditions. Thus, under the lowest unit-price condition, baboons responded one to three times during each 30-s ITI, regardless of the number of pellets per delivery.

As demonstrated by the cumulative intake curves (Figure 2), food intake occurred in bouts, with periods of responding leading to multiple reinforcers separated by periods of no responding. In order to examine the topography of a bout of responding, data from the first bout (or meal) of the day were analyzed separately. Figure 5 presents cumulative intake during the first bout for 2 baboons under the initial one-pellet and the 10-pellet conditions as a function of unit price. Reinforcer deliveries under both conditions and unit prices occurred at a consistent rate until the baboon stopped responding (as defined by a pause greater than 10 min). The pauses during the first bout were of similar length throughout the bout, and, as described for mean pause length for the entire session, longer under the multiple-pellet conditions.

The top panels of Figure 6 present mean pellet intake during the first meal (food eaten during the first bout) as a function of unit price and pellet condition. The size of the first meal decreased as unit price increased under all conditions. Also, size of the first meal tended to be smaller under the multiple-pellet conditions than under the one-pellet condition. The bottom panels of Figure 6 present mean running rate during the first meal as a function of unit price and pellet condition. Running rate during the first meal was not affected systematically by unit price under all conditions (ignoring the running rate under the one-pellet condition at the lowest response cost). As with mean running rate for the entire session, running rates were lowest under the multiple-pellet conditions.

DISCUSSION

The results of the present study demonstrate the utility of using demand functions to study motivational variables. When responding was maintained by the delivery of a single food pellet, food intake remained stable as the FR value increased to about 16 for one group of baboons and 32 for another group of baboons. Food intake decreased when FR values were further increased. Increasing the number of food pellets per reinforcer decreased total re-

sponding and the number of reinforcements per day. A unit-price analysis, which converted intake to grams per day and cost to the number of responses to obtain 1 g, yielded demand functions that overlapped at lower unit prices. Although intake under the single- and multiple-pellet conditions overlapped at the lowest unit prices, response rates and postreinforcement pausing varied among the conditions at the same unit prices.

As previously reported, when the number of pellets per reinforcement were increased, responding by baboons decreased, resulting in fewer reinforcements but stable total daily food intake (Foltin, 1992). The finding that increasing reinforcement magnitude did not increase total intake contrasts with data reviewed by Allison, Miller, and Wozny (1979). These authors noted that, under a wide range of circumstances and in a wide variety of experimental subjects, increasing reinforcement magnitude decreased total responding but increased intake. Baboons and rhesus monkeys differ from other laboratory animals in that these species show greater caloric regulation under a wide range of laboratory conditions (e.g., Foltin & Fischman, 1990; Hout, 1982; McHugh & Moran, 1978). The lack of consistent increases in daily food intake as reinforcement magnitude increased is probably a consequence of the 23-hr session length in combination with caloric regulation.

The main purpose of this study was to provide a unit-price analysis of demand for food. A unit-price analysis takes into account common features shared by commodities and the effort necessary to obtain them by expressing responding as effort per unit of the reinforcer (Allison, 1979; Bickel et al., 1990; Collier et al., 1986; Hursh et al., 1988). The unit-price hypothesis predicts that a single function relates consumption of a commodity to cost of that commodity, such that converting to unit price will result in substantially overlapping demand functions. In the present case, food intake was converted to grams per day and the response requirement was converted to responses per gram. Comparing the single- and multiple-pellet conditions based on unit price yielded two findings: (a) Response topography varied among conditions at the same unit prices and same level of total daily food intake; and (b) unexpectedly, under one or more multiple-pellet conditions, total daily intake decreased more rapidly with increasing unit price than

Fig. 5. Cumulative pellet intake in grams during the first meal of the session for a representative baboon from Group 1 (top panels) and Group 2 (bottom panels) obtained under the initial one-pellet condition and the 10-pellet condition at the lowest and highest unit price that both conditions had in common. Note *x*-axis scale change in bottom right panel. See Figure 2 for details.

Fig. 6. Mean size of the first meal (top panels) and mean running response rate during the first meal (bottom panels) as a function of unit price (responses per gram) under the one-pellet condition (mean of three determinations) and both multiple-pellet conditions. See Figure 1 for details.

it did under the average one-pellet condition in 7 of 8 baboons.

Under all pellet conditions and unit prices, responding typical of FR schedules was observed, with pauses after reinforcer delivery followed by responding at a consistent rate until the next ratio requirement was completed. With few exceptions (<10 per session), once a baboon initiated a ratio, he completed that ratio, regardless of the unit price. Finally, across all conditions, baboons responded one to three times during each ITI. There were three topography measures that clearly differentiated the one-pellet condition from the multiple-pellet conditions at the same unit prices and same levels of daily food intake: (a) Pauses between reinforcer delivery and the initiation of a new ratio were longer under the multiple-pellet conditions, (b) running response rate was consistently lower under the multiple-pellet conditions, and (c) the number of pellets consumed during the first meal was smaller under the multiple-pellet conditions.

The mean pause after reinforcement was directly related to the number of pellets per delivery. Under the lowest unit-price conditions, baboons paused an average of 3, 15, and 30 min under the one-, five-, and 10-pellet conditions, respectively. Across all conditions, increasing the unit price increased pause length. In contrast, running response rates, lower under multiple-pellet conditions, were unaffected by unit price. Higher response rates with smaller food packages have also been reported by Collier et al. (1986) in rats responding for food. In contrast to the current results, Collier et al. reported that the rate of responding by rats also increased with increasing cost. The consistent response rates across all unit prices (except the lowest cost under the one-pellet condition) replicate earlier data obtained with baboons responding for one pellet (Foltin, 1991). Another way in which the current results differ from those reported with rats (Collier et al., 1986) is that larger package sizes resulted in smaller meals. Although there were several procedural differences between this study and that of Collier et al., both studies indicate that analysis of feeding topography at varying unit prices can provide information useful to understanding factors controlling behavior; this information was not evident based on measures of total daily responding or food consumption.

In a study involving a unit-price analysis of food intake in rats, Hursh et al. (1988) reported that one of the conditions with multiple pellets did not follow the unit-price demand functions generated by the other conditions. The present results also suggest that deviations from the unit-price function may be evident. Although total food intake decreased more quickly with increasing unit price under one or both multiple-pellet conditions compared to the one-pellet condition (especially for the baboons in Group 1), there are several methodological issues that limit the interpretation of the results. First, the FR values were in effect for only 2 or 3 days. Although in our laboratory this procedure has resulted in stable and reliable patterns of responding (Foltin, 1991, 1992) under one-pellet conditions, it is possible that responding for multiple pellets had not stabilized under the larger unit prices. Second, the rate of food intake was not controlled, such that under the multiple-pellet conditions baboons could consume pellets more quickly (e.g., five pellets after 10 responses compared to one pellet after two responses). The mean pause-time data indicate that baboons paused longer after receiving multiple pellets, thus minimizing differential rate effects on food consumption. Also, running response rate was lower under the multiple-pellet conditions, tending to stabilize rate of intake across conditions. Third, the deviations from the unit-price hypothesis varied among baboons and were not consistently related to one package size or the other. Although variable among baboons and influenced by limited exposure to each unit price, the results suggest that deviations from the unit-price hypothesis should be examined within each data set prior to combining across costs and amount of the commodity.

Economic analyses of operant behavior have been of great benefit in studying the factors that affect consumption of a commodity (Allison, 1979, 1981, 1983; Hursh, 1980, 1984; Hursh & Bauman, 1987; Lea, 1978). The results of the present study suggest that the number of pellets per food delivery may affect, in unexpected ways, demand for food. Although procedural issues require a conservative endorsement of that finding, the results clearly indicate that response topography under the same unit prices varied as a function of package size. These findings support the heuristic

value of a unit-price analysis for studying responding for, and consumption of, commodities that have similar attributes, but also indicate that different response topographies may result in similar intakes of a commodity.

REFERENCES

- Allison, J. (1979). Demand economics and experimental psychology. *Behavioral Science*, 24, 403-415.
- Allison, J. (1981). Economics and operant conditioning. In P. Harzem & M. D. Zeiler (Eds.), *Predictability, correlation, and contiguity* (pp. 321-353). New York: Wiley.
- Allison, J. (1983). *Behavioral economics*. New York: Praeger Publishers.
- Allison, J., Miller, M., & Wozny, M. (1979). Conservation in behavior. *Journal of Experimental Psychology: General*, 108, 4-34.
- Bickel, W. K., DeGrandpre, R. J., Higgins, S. T., & Hughes, J. R. (1990). Behavioral economics of drug self-administration. I. Functional equivalence of response requirement and drug dose. *Life Sciences*, 47, 1501-1510.
- Bickel, W. K., DeGrandpre, R. J., Hughes, J. R., & Higgins, S. T. (1991). Behavioral economics of drug self-administration: II. A unit-price analysis of cigarette smoking. *Journal of the Experimental Analysis of Behavior*, 55, 145-154.
- Collier, G. H., Johnson, D. F., Hill, W. L., & Kaufman, L. W. (1986). The economics of the law of effect. *Journal of the Experimental Analysis of Behavior*, 46, 113-136.
- DeGrandpre, R. J., Bickel, W. K., Hughes, J. R., & Higgins, S. T. (1992). Behavioral economics of drug self-administration: III. A reanalysis of the nicotine regulation hypothesis. *Psychopharmacology*, 108, 1-10.
- Foltin, R. W. (1991). An economic analysis of "demand" for food in baboons. *Journal of the Experimental Analysis of Behavior*, 56, 445-454.
- Foltin, R. W. (1992). Economic analysis of caloric alternatives and reinforcer magnitude on "demand" for food in baboons. *Appetite*, 19, 255-271.
- Foltin, R. W., & Fischman, M. W. (1990). Effects of caloric manipulations on food intake in baboons. *Appetite*, 15, 135-149.
- Houpt, K. A. (1982). Gastrointestinal factors in hunger and satiety. *Neuroscience and Biobehavioral Reviews*, 6, 145-164.
- Hursh, S. R. (1980). Economic concepts for the analysis of behavior. *Journal of the Experimental Analysis of Behavior*, 34, 219-238.
- Hursh, S. R. (1984). Behavioral economics. *Journal of the Experimental Analysis of Behavior*, 42, 435-452.
- Hursh, S. R., & Bauman, R. A. (1987). The behavioral analysis of demand. In L. Green & J. H. Kagel (Eds.), *Advances in behavioral economics* (pp. 117-159). Norwood, NJ: Ablex Publishing Corporation.
- Hursh, S. R., Raslear, T. G., Shurtleff, D., Bauman, R., & Simmons, L. (1988). A cost-benefit analysis of demand for food. *Journal of the Experimental Analysis of Behavior*, 50, 419-440.
- Lea, S. E. G. (1978). The psychology and economics of demand. *Psychological Bulletin*, 85, 441-466.
- McHugh, P. R., & Moran, T. H. (1978). Accuracy of the regulation of caloric ingestion in the rhesus monkey. *American Journal of Physiology*, 235, R29-R34.

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APPENDIX

Pellet intake as a function of unit price under each condition by each baboon.

Subject	Initial one pellet		One pellet (2)		One pellet (3)		Five pellets/ delivery		10 pellets/ delivery	
	Unit price ^a	Intake	Unit price	Intake	Unit price	Intake	Unit price	Intake	Unit price	Intake
1	2	424	2	282	2	334	2	585	2	430
	8	377	8	216	8	419	8	370	8	410
	16	385	16	222	16	311	16	390	16	290
	32	247	32	113	32	214	24	280	24	160
	48 ^b	133	48 ^b	77	48 ^b	87	32 ^b	165		
2	2	447	2	357	2	357	2	420	2	520
	8	446	8	321	8	281	8	380	8	420
	16	354	16	259	16	283	16	145	16	90
	32	192	32	145	32	196	24	60	24	170
	48 ^b	68			48 ^b	143				
3	2	676	2	266	2	435	2	565	2	550
	16	547	8	310	16	427	8	445	8	590
	32	455	16	351	32	349	16	345	16	520
	64 ^b	188	32	229	48 ^b	169	24	225	24	220
	128 ^b	19	48 ^b	192						
4	2	704	2	618	2	768	2	820	2	640
	16	554	16	538	16	662	8	690	8	690
	32	586	32	439	32	591	16	550	16	680
	64	335	64	318	64	373	32	440	32	510
	128	160	128	153	128	292	40	420	40	450
							56 ^b	340		
5	2	397	2	188	2	330	2	480	2	520
	16	324	16	163	16	354	8	435	8	400
	32	331	32	221	32	286	16	455	16	420
	64	265	64	206	64	249	32	390	32	320
	128	179	128	163	128	90	40	315	40	270
							56 ^b	315		
6	2	436	2	255	2	379	2	405	2	410
	16	255	16	256	16	535	8	320	8	310
	32	326	32	311	32	343	16	305	16	370
	64	216	64	224	64	269	32	175	32	280
	128	201	128	212	128	154	40	265	40	240
							56 ^b	245		
7	2	390	2	347	2	333	2	385	2	350
	16	373	16	324	16	449	8	435	8	390
	32	356	32	311	32	294	16	410	16	420
	64	193	64	273	64	267	32	350	32	170
	128	84	128	127	128	72	40	265	40	140
							56 ^b	160		
8	2	858	2	675	2	601	2	875	2	740
	16	632	16	588	16	980	8	630	8	900
	32	528	32	610	32	755	16	635	16	740
	64	321	64	216	64	554	32	655	32	460
	128	56	128	119	128	223	40	455	40	330
							56 ^b	275		

Note. Baboons 1, 5, 7, and 8 received five pellets then 10 pellets; Baboons 2, 3, 4, and 6 received 10 pellets then five pellets.

^a Responses per gram.

^b A data point not summarized in the figures.