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5 The Elasticity of Demand for Sucrose Solutions in Common Marmosets

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I. Introduction

Sensitivity to reinforcing consequences is essential for animal learning. In this study we examine marmosets' sensitivity to concentrations of sucrose solutions. We determine demand curves for two different concentrations of sucrose solutions and assess the elasticity of demand for those solutions.

In a previous study (Ishii & Watanabe, in press), we examined the marmosets' licking behavior in the course of experimental sessions where sucrose solutions were freely available from a drinking tube for a duration of 30 minutes. The concentration of sucrose solutions was 1%, 5%, or 25% in different conditions. The results showed that licking rates decreased monotonically regardless of the concentrations and that the decreasing patterns could be reasonably explained by exponential functions. The rates of decrease were slowest for the 5% solution and fastest for the 1% solution. The overall numbers of licks at the 5% and 25% solutions were almost same, while those at the 1% solution were fewer.

Ishii and Watanabe's (in press) study seemingly revealed that marmosets' behavior is differentially responsive to different concentrations of sucrose solutions. However, to examine whether marmosets' behavior is truly susceptible to the reinforcing function of sucrose solutions, we should show that some arbitrary behavior—instead of consummatory behavior such as licking—can be reinforced by sucrose solutions. Therefore in the present study we reinforce marmosets' lever pressing behavior with fixed-ratio (FR) schedules of the presentation of sucrose solutions. Further, by changing the response requirements of the FR schedules systematically, we determine the demand curves for sucrose solutions.

Demand curves denote the amount of consumption of a particular commodity as a function of its price. In animal experiments, an arbitrary response is used as an analogue of currency, and the number of responses required to obtain a reinforcer is regarded as the price of the reinforcer (e.g., Hursh, 1978). Then, to determine demand curves for a particular reinforcer in animal experiments, we plot the number or the amount of obtained reinforcers as a function of the required number of responses per reinforcer.

When a certain type of reinforcer is used, the amount of consumption may decrease less than proportionally to the increase in the price; when some other type of reinforcer is used, it may decrease more than proportionally to the increase in the price. The steepness of the (negative) slope of a demand curve is called the elasticity of the demand for a reinforcer. When an elastic reinforcer is used, animals do not compensate for the increase in price by increasing their response rates; as a result, the amount of consumption of the reinforcer decreases. When an inelastic reinforcer is used, the opposite is the case. In the present study, we examined if sucrose solutions of different concentrations are differentially elastic.

II. Method

1. Subjects

The same two common marmosets (*Callithrix jacchus*) as the ones used in Ishii and Watanabe's (in press) experiment served as the study subjects. One of them (I3441F) was female, and the other (I3613M) was male; they were both provided by CLEA Japan, Inc., and were approximately 21 months old at the start of the experiment. They were housed in individual cages with 24 h water access. The room in which the cages were located was lit from 8:00 a.m. to 8:00 p.m. Experimental sessions were conducted individually before a once-daily ration of food was provided to the marmosets at around noon. Their daily food ration was 28 grams of marmoset chow (CMS-1M, CLEA Japan, Inc.) macerated with a mixture of water, honey, and vitamins, with a spoon of milk powder on top. Since this was the standard amount of daily food used by the animal supplier to maintain marmosets at their free-feeding weight, and because we always found dry, but still edible remains of food in their food trays just before the sessions, we assumed that the subjects were not deprived of food.

2. Apparatus

One operant chamber (W × D × H, 33.5 × 31.5 × 31.5 cm), specially produced by SHIMAELE, Co., Ltd. was used. The front wall of the chamber was made of aluminum and the other three walls, the ceiling, and the floor were made of stainless steel grids. A water bottle was fixed behind the front wall, the nozzle of which could be inserted into the chamber through a hole located at the center of the front wall. A capacitance sensor was attached to the nozzle to detect when the marmosets licked the tip of the nozzle, which was located 11.5 cm above the floor and projected 1.2 cm into the chamber. The body of the nozzle (apart from its tip) was covered by a rubber tube and was insulated. A white LED light was located above the hole for the nozzle presentation, 15 cm above the floor. This white LED was lit during the period when the nozzle was inserted into the chamber. Two slits for inserting retractable response levers were set at 11 cm above the floor. The slits were set apart from the hole for the nozzle presentation by 6 cm to the left and to the right, respectively. Only the right lever was used in the present experiment. This lever was 3 cm wide and 0.3 cm thick, and could be projected 2.8 cm into the chamber. Two straight arrays of white LEDs were attached to the chamber's ceiling to provide general illumination. During the experiment, 83-dB white noise emanated from two speakers placed outside the chamber, 50 cm away from the rear wall. The chamber itself was placed in a dark room. A personal computer in the room controlled the stimulus presentation and recorded the licking and lever pressing responses of the marmosets.

3. Procedure

3.1. Preliminary training

A modified autoshaping procedure was employed to shape the lever press responses of the marmosets. At the onset of a trial, the right lever was inserted into the chamber. If the lever was not pressed for 12 s, it was withdrawn automatically, and the nozzle of the water bottle was inserted. The water bottle contained a 7% (0.20 mol/L) sucrose solution. The nozzle remained presented for 6 s. After the presentation of the nozzle, an intertrial interval started, during which only the general illumination and the white noise was on. The duration of the intertrial interval was randomly selected from a uniform distribution ranging from 24 to 72 s. After the intertrial interval, the next trial began with the presentation of the right lever. If the lever was pressed within 12 s, it was immediately withdrawn, and, at the same time, the 6-s nozzle presentation was set underway. In this case, the intertrial interval did not follow the nozzle presentation; instead, the lever was inserted immediately, and the next nozzle presentation occurred whenever the lever was pressed within 300-s after the last presentation of the nozzle. If the lever was not pressed for 300 s, then the intertrial interval would start. Therefore, in this method, a standard autoshaping procedure or the pairing of the lever and the nozzle presentation was repeated unless the lever was pressed, and once the lever was pressed, the lever press responses were reinforced continuously. An experimental session lasted 45 minutes.

After the lever press responses were acquired successfully, additional training was employed for three sessions. In these sessions, lever pressing was continuously reinforced with the 7% sucrose solution. These sessions lasted for 30 minutes each.

3.2. Determination of demand curves

In 30-min sessions, the marmosets' lever press responses were reinforced with fixed ratio (FR) schedules of the presentation of sucrose solutions. The duration of a presentation was 4.5 s for Marmoset I3441F and 3 s for Marmoset I3613M, because the former marmoset licked the nozzle more slowly than the other. In a series of sessions carried out to determine a demand curve, the required number of responses per reinforcer was set at one for the first two sessions, and then the number was doubled from session to session. When the response requirement became so severe that no reinforcer was earned in a session, a new series of sessions was begun with an FR 1 schedule to determine another demand curve. Between conditions, the concentrations of the sucrose solutions were changed; it was 5% (0.15 mol/L) in the first and third series of sessions and 20% (0.60 mol/L) in the second and fourth series of sessions.

III. Results

Figure 1 shows the number of reinforcers earned in a session as a function of the response requirement of FR schedules. The abscissae and ordinates are logarithmic. Marmoset I3441F earned fewer reinforcers in the first determination of the demand curve for the 5% sucrose solution than in the other determinations. This marmoset could earn at least one reinforcer up until the FR 128 schedules. The number of reinforcers earned by Marmoset I3613M varied substantially across determinations. This marmoset earned some reinforcers even when 512 responses were required per reinforcer. The observation of the videotaped records revealed that the topography of the lever pressing changed across sessions: in the first and fourth series of sessions, discrete lever presses were emitted, whereas in the second and third series of sessions Marmoset I3613M held the lever and moved it up and down without releasing it.

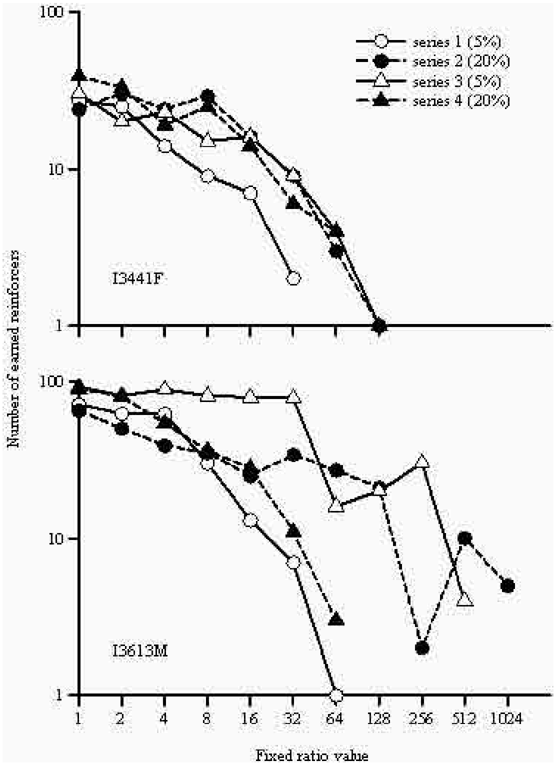

Figure 1. Obtained demand curves

The number of lever presses in a 30-min session was plotted as a function of the FR value in Figure 2. The number of lever presses by I3441F increased as the FR value increased, peaked at modest FR values, such as FR 16 to 64, and then decreased when the response requirement became more severe. The number of lever presses for I3613M showed a similar pattern, but the absolute numbers varied substantially across the series of sessions. In both the marmosets, the number of lever presses did not change systematically as a function of the concentration of sucrose solutions.

To examine if the model proposed by Hursh and Silberberg (2008) accounts for the present data, Eq.1 was fit to the averages of the numbers of earned reinforcers that are shown in Figure 1:

$$\log Q = \log Q_0 + k(e^{-\alpha P} - 1), \tag{1}$$

where k and α are free parameters, Q is the number of obtained reinforcers, Q_0 is the highest level of demand or the maximum of Q, and P is the price or the

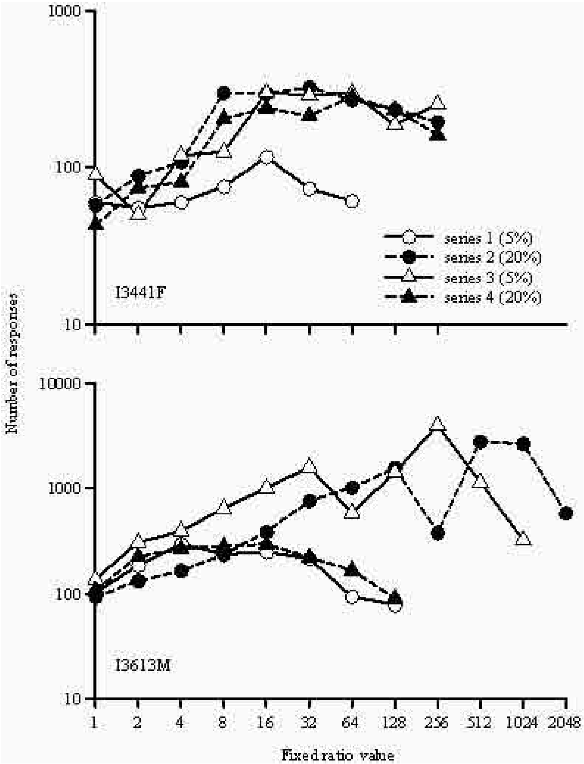

Figure 2. Number of lever pressess as a function of Fixed ratio values

number of required responses per reinforcer. The parameter α determines the rate of decline in relative consumption (log consumption) with increases in price, which is the elasticity (Hursh & Silberberg, 2008). Only the data for I3441F were used in this fitting, because the data for I3613M varied substantially. The averaged data and best-fitting curves are shown in Figure 3. The best-fitting curves accounted for more than 98% of variances of the data. The values of the parameters used for the fitting were summarized in Table 1. Not surprisingly, the parameter values were similar between the demand for the 5% solution and that for the 20% solution.

IV. Discussion

Marmoset I3441F changed the amount of consumption of sucrose solutions and the number of lever presses systematically with the change in the FR value. These results mean that this marmoset's lever pressing behavior was susceptible to the

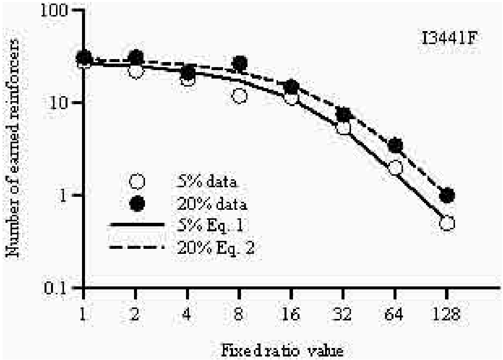

Figure 3. Average demand curves and theoretical curves

Table 1. Best-fiting parameters of Eq.1

Concentrations	Q_0	k	α
5%	29	4.9	0.013
25%	32	4.7	0.010

reinforcing function of sucrose solutions. However, the difference in the concentrations of sucrose solutions did not affect the rate of decline in the demand curves. In other words, the demands for the 5% solution and that for the 20% solution were similarly elastic. We need a wider range of concentrations of sucrose solution to determine how the concentration affects the elasticity of demand such solutions.

Marmoset I3613M also changed the amount of consumption and the number of lever presses with changes in the FR value. However, the changes were not systematic because the topography of lever pressing behavior changed across the series of sessions. The change of topography changed the definition of currency in the present experiment and made it difficult to determine demand curves. In a future study, we may need to train this marmoset to respond more uniformly or get it to employ some other behavior that is naturally uniform in the topography.

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