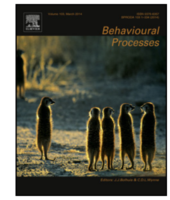
Behavioural Processes 128 (2016) 47–52

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc



Demand in rats responding under duration-based schedules of reinforcement☆

Sara Peck, Tom Byrne*

Massachusetts College of Liberal Arts, United States

ARTICLE INFO

Article history:
Received 20 February 2016
Received in revised form 4 April 2016
Accepted 4 April 2016
Available online 6 April 2016

Keywords:
Demand
Response duration
Continuous dimension
Reinforcement
Lever pressing
Rats

ABSTRACT

In two experiments, demand curves were generated by exposing rats to a sequence of fixed-duration schedules in which the response requirement doubled each experimental session. Holding down the response lever for the requisite amount of time resulted in the delivery of sweetened condensed milk. Response durations shorter than those required for reinforcer delivery did not result in any programmed consequences, nor were cumulative durations across multiple presses applied towards the duration requirements. The number of reinforcer deliveries decreased as a function of reinforcer requirements. Reinforcer delays alone also decreased consumption, but to a lesser extent than increasing duration requirements. Results are congruent with previous research demonstrating that parameters of reinforcement schedules may have similar effects on both continuous and discrete dimensions of operant behavior. Hursh and Silberberg's (2008) exponential demand equation provided a good fit for several of the data sets.

1. Introduction

With few exceptions (*e.g.* Alling and Poling, 1995; Zarcone et al., 2007), schedules of reinforcement in laboratory investigations of operant behavior have historically been arranged for discrete responses rather than continuous measures of behavior (Williams and Johnson, 1992). One continuous dimension of behavior that has received little attention is duration. Although occasionally used in applied research to measure bouts of functionally-related operants (Mudford et al., 2009), response duration may refer to the time that elapses between the start and termination of a single response. For example, the duration of a lever press would be the interval between depression and release of the response lever. Duration may be of interest in that reinforcement contingencies outside of the laboratory may sometimes act upon continuous rather than discrete dimensions of behavior (Morgan et al., 2009; Williams and Johnson, 1992)

When reinforcer delivery is contingent upon response duration, data suggest that duration may be similar to response rate in how it is influenced by schedule parameters. Stevenson and Clayton (1970) trained rats to hold down response levers for a duration of 40 s for food reinforcement. Subsequently, response durations decreased during extinction, and reinstatement was evident once reinforcer delivery resumed. Rider and Kametani (1987) compared responding under schedules of reinforcement arranged for fixed *versus* variable durations of responding. Performance on the two schedules was comparable to that associated with analogous fixed- and variable-ratio schedules. Specifically, shorter post-reinforcement pauses were evident under the variable-duration schedules compared to the fixed-duration schedule. Similar differences are found when comparing fixed to variable ratio schedules (Ferster and Skinner, 1957) In addition, the variable schedule engendered longer durations than the fixed schedule. Correspondingly, response rates generated by variable-ratio schedules are typically higher than those generated by fixed-ratio schedules (Ferster and Skinner, 1957).

Given the dearth of research on response duration, the relationship between response duration and escalating reinforcer requirements is largely unknown. One technique for systematically evaluating relationships between reinforcer requirements and behavior is the generation of demand curves. Procedures frequently involve testing a variety of fixed-ratio requirements and plotting reinforcers earned as a function of those requirements (Foster et al., 1997; Madden et al., 2005). Doing so produces orderly results with the number of reinforcer deliveries decreasing as a function of ratio

☆ We wish to thank the two anonymous reviewers for their thoughtful comments on a previous version of this article. We are indebted to Amanda Hoag and Taylor Manning for their assistance in running experimental sessions.
* Corresponding author at: MCLA, Department of Psychology, 375 Church St., N. Adams 01247, United States.
E-mail address: t.byrne@mcla.edu (T. Byrne).

http://dx.doi.org/10.1016/j.beproc.2016.04.002
0376-6357/

size. In the language of behavioral economics, ratio requirements are indicative of "price" and reinforcer deliveries are indicative of "consumption". The relationship between price and consumption may be well described by the following equation developed by Hursh and Silberberg (2008):

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

Although a detailed analysis of the derivation and application of this equation is beyond the scope of this paper, each component is relevant to behavior emitted under ratio schedules. The variable C is set by the experimenter and represents cost (*i.e.* ratio requirement). The variable Q is a dependent measure and represents consumption (*i.e.* reinforcers earned). Q_0 is an estimate of how much consumption would occur if price were zero. *K* is a constant set by the experimenter to capture the observed range of the dependent variable in logarithmic units. The parameter α is a measure of elasticity which reflects the rate at which consumption changes as a function of price. There have been several promising demonstrations of the descriptive value of this equation in addition to those provided by Hursh and Silberberg (*e.g.* Cassidy and Dallery, 2012; Christensen et al., 2009).

Although demand curves are used typically to assess the elasticity of demand for different commodities (reinforcers), they may provide utility for testing if increasing price has consistent effects across different dimensions of behavior. To our knowledge, there have been no attempts to generate demand curves by setting price according to fixed-duration values. The purpose of the current study was to (a) test if systematic increases in price defined by duration instead of the number of discrete responses would produce orderly decreases in consumption, and (b) test if relationships between consumption and price as set by response-duration requirement would be well described by Hursh and Silberberg's exponential demand equation.

2. Experiment 1

2.1. Methods

2.1.1. Subjects

Four male Sprague-Dawley rats, approximately 17 months of age at the start of the study, served as subjects. All rats had prior lever-pressing experience. Rats were housed in groups of four with unlimited access to food and water and were subject to 12:12 h light/dark cycle. Procedures were approved by an Institutional Animal Care and Use Committee at MCLA and the research was conducted in accordance with the *APA Ethical Principles of Psychologists* (http://www.apa.org/science/leadership/care/guidelines.aspx).

2.1.2. Equipment

Four MED Associates (St. Albans, VT) operant test chambers were used. Chambers were 30.5 cm long by 24.1 cm wide by 21.0 cm high. One response lever was mounted on the front panel 7 cm above the chamber floor. A force of 0.25 N activated the microswitch. A receptacle located in the center of the front panel 3 cm above the chamber floor allowed access to sweetened condensed milk (Borden Eagle Brand©, Borden Co., Sapulpa, OK) provided by a liquid dipper. The dipper cup was 0.01 cc, but sweetened condensed milk adhering to the sides of the cup make this measure an estimate only. Sweetened condensed milk was diluted with water resulting in a 75/25 (v/v) milk to water solution. Dilution eliminated adhesion of the dipper arm to the receptacle. Chambers were enclosed in sound-attenuating boxes equipped with a fan to provide ventilation and sound masking. A house light was illuminated during all sessions. All environmental events were controlled

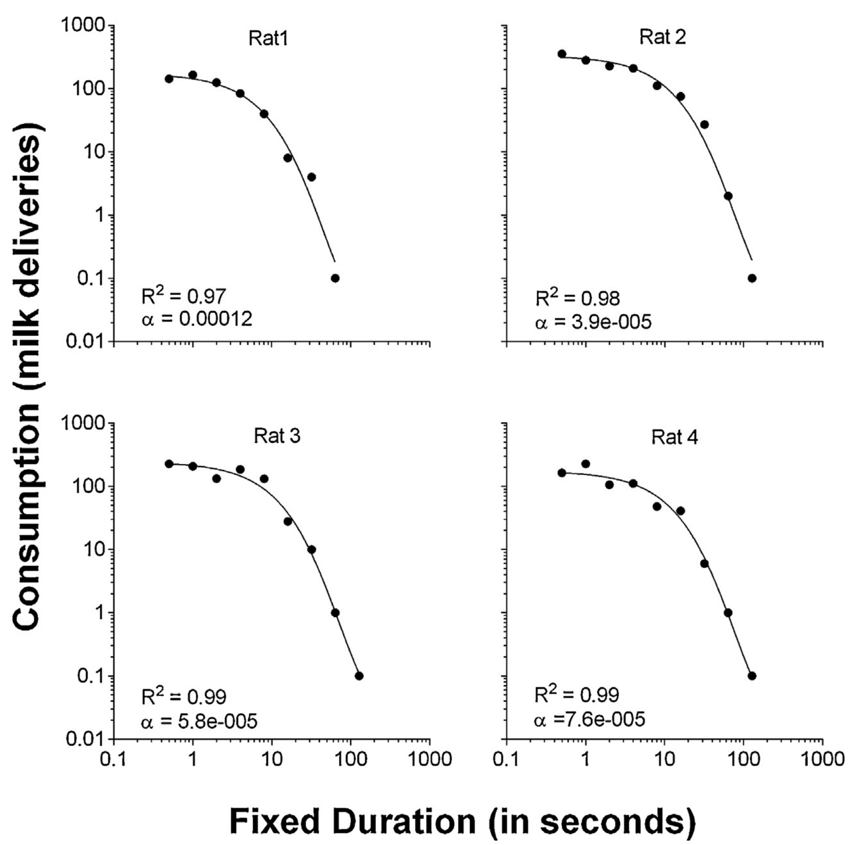


Fig. 1. The fit of the exponential-demand equation to data for each rat in Experiment 1. Variance accounted for (R^2) is shown in each panel.