



Short report

## Force dynamics in fixed-ratio schedules

Jonathan W. Pinkston\*, Lindsey N. McBee

University of North Texas, United States

### ARTICLE INFO

#### Article history:

Received 26 July 2013

Received in revised form 1 November 2013

Accepted 12 November 2013

Available online 4 December 2013

#### Keywords:

Force

Fixed ratio

Dynamics

Inter-response time

Rat

Press

### ABSTRACT

Fixed-ratio schedules are widely used in behavioral research. Although fixed-ratio schedules often conjure up relationships to work and effort, little is known about effort-related measures in these schedules. Early research had shown that force and effort of operant behavior vary systematically during the execution of ratio schedules, and the goal of the present study was to revisit early research on force dynamics in fixed-ratio schedules. Four rats earned sucrose by pressing an isometric force transducer. Presses produced sucrose after ten or twenty responses. In general, the force of responses increased then decreased systematically across the ratio. The possibility that decreases in force during ratio execution was due to a trade-off with the differential reinforcement of short inter-response times (IRT) was investigated in an additional condition where sucrose was made available according to a tandem fixed-ratio 19 inter-response (IRT) > t schedule. The tandem IRT requirement did not eliminate decreasing trends in force across the ratio; unexpectedly, the tandem requirement did eliminate increases in force early in the ratio, which may reflect sequence-level organization operating in the control of force dynamics.

© 2013 Elsevier B.V. All rights reserved.

### 1. Introduction

Fixed-ratio (FR) schedules are a mainstay of behavior research; they are commonly used to set the work requirement in basic schedule and applied research (e.g., Ferster and Skinner, 1957; Schlinger et al., 2008; Van Houten and Nau, 1980; Williams et al., 2011) and are commonly used in studies of response effort (e.g., Brackney et al., 2011; Ghods-Sharifi and Floresco, 2010). Although FR schedules often conjure up ideas of “work” and “effort”, it is notable that little is known about force dynamics of operant behavior under fixed-ratio schedules. Early work by Notterman and Mintz (1965) examined a number of effort-related variables affected by FR schedules; in particular, they found forces changed in orderly ways as a function of ordinal response position. Specifically, forcefulness of operant behavior appears to increase as the ratio is executed. Notterman and Mintz interpreted the increases in force as due to an extinction effect because periodic reinforcement resulted in an immediate reduction in force. Once responses did not meet reinforcement, however, force began increasing in a negatively accelerating pattern.

Our lab recently began to follow-up on Notterman and Mintz's initial findings, as they had lain dormant for nearly 40 years. In our first studies, we found that we could reproduce the increases in

force as a function of response position, but in contrast to Notterman and Mintz's findings, forces followed a bitonic function, rising and falling as the ratio was completed. Accepting Notterman and Mintz's interpretation of the rise in operant force as due extinction, we considered that the falling edge of the function could be due to the local exigencies of FR schedules; specifically, FR schedules differentially reinforce response bursting, which may work to reduce force because more forceful responses generally take longer to execute (Notterman and Mintz, 1965). If so, adding a tandem IRT requirement to the end of the FR schedule should eliminate the falling edge of the function. The present study documents our attempts to replicate the early work of Notterman and Mintz, and our attempt to understand reductions in force as responses are executed.

### 2. Method

#### 2.1. Subjects

Four male Sprague Dawley rats were used. R1 and R2 had experience with various schedules of reinforcement and were 11 months old at the start of the study; R5 and R6 had worked on continuous schedules of reinforcement and were 4 months old. Rats were housed in pairs in a steel hanging cage in a colony room that operated on a reversed 12 h:12 h light:dark cycle. Each rat was deprived to 85% of its free-feeding weight for the duration of the study (actual day-to-day values ranged from 83% to 88%); deprivation was maintained by post-session feedings. Water was continuously available in the home cage. Experimental sessions were conducted 7 days per

\* Corresponding author at: Department of Behavior Analysis, 1155 Union Circle #310919, Denton, TX 76203-5017, United States. Tel.: +1 940 369 8416; fax: +1 940 565 2467.

E-mail address: [jonathan.pinkston@unt.edu](mailto:jonathan.pinkston@unt.edu) (J.W. Pinkston).

week and began 1 h into the dark cycle. All procedures used were approved by the Institutional Animal Care and Use Committee at the University of North Texas.

## 2.2. Apparatus

Experiments were conducted in custom operant chambers. Internal dimensions were 23 cm × 25 cm × 27 cm. One wall was made from aluminum and served as the intelligence panel; the remaining walls were Plexiglas™. A 12-V lamp mounted near the ceiling provided general illumination. A 2 cm × 2.5 cm window was located on the left side of the wall; the bottom edge was 1.5 cm above the floor. The window provided access to an isometric force transducer (Model 31, Sensotec, Columbus, OH, USA) that served as the operandum. A 1.2-cm diameter aluminum disk was mounted to the transducer and positioned such that its horizontal surface was level with the bottom edge of the window, 1 cm from the outside of the wall. The method of locating the operandum outside the chamber functions to control the animal's topography; the positioning of the transducer ensured that only the animal's forelimb could come into contact with the disk, and thus all recorded forces would measure presses. A 2 cm<sup>2</sup> receptacle was recessed into the intelligence panel, located medially on the aluminum wall. Once schedule requirements were satisfied, a 12-V lamp in the receptacle was illuminated and a 0.1-ml drop of 15% (w/v) sucrose solution made available via a Gerbrands™ dipper.

During sessions, data from transducers were amplified (Model UV, Sensotec, Columbus, OH, USA) and recorded using a 12-bit A-D acquisition card (USB-6099, National Instruments, Austin, TX, USA). A response was defined when forces exceeded and then fell below 3.2 g. White noise at 70 dB was present in the room where experiments were conducted. All experimental events and data collection were accomplished by software written in Labview™ (National Instruments, Austin, TX, USA).

## 2.3. Procedure

### 2.3.1. Fixed ratio 10

In the first condition, we examined the forces of operant responses under a fixed-ratio (FR) 10 schedule. At the beginning of the session, the houselight was illuminated. Every 10th response delivered sucrose; sessions ended after 30 deliveries. Conditions lasted when both the average response rate and average peak force, defined as the maximum force exerted in executing the response, met our stability criteria. Stability for all conditions was assessed after a minimum of 20 days. To meet stability, response rate over the most recent 6 days were assessed; to determine stability, each successive pair of points were averaged and measures were judged stable when none of the six data points contained the highest or lowest values observed in the condition, the three pairs showed neither a decreasing or increasing trend, and the three pairs of means did not differ from the six-day mean by more than 15%.

### 2.3.2. Fixed ratio 20

Following the completion of the FR 10 condition, the ratio requirement was increased to 20. Other procedural details remained constant.

### 2.3.3. Tandem FR 19 IRT > t

We observed that operant forces follow a bitonic function as the ratio schedule is executed and speculated that the reduction in force is a trade-off that permits increased execution speed arising from the FR schedule's tendency to reinforce short interresponse times (IRTs). To test our hypothesis, the schedule was changed to a Tandem FR 19 IRT > t schedule. For Rats 5 and 6, t was set to 2 s. Rat 1 did not maintain responding at 2 s, and after many sessions t

was set to 1 s. Rat 2 did not maintain stable performance at any IRT requirement tested and so did not participate further in the study. The tandem schedule maintains the nominal schedule requirement (20 responses), but prohibits the differential reinforcement of short IRTs. Thus, if force decreases observed at the end of the ratio were due to differential reinforcement of short IRTs, then the tandem requirement should reduce or eliminate the decreasing pattern. Stability under the tandem schedule was assessed as in the other conditions.

## 3. Results

Under stable conditions, responses rates under the FR 10 schedule were 118.8, 110.7, 120.2, and 85.6 responses/min for R1, R2, R5, and R6, respectively. Increasing the ratio value to 20 decreased rate in three of the four rats; values were 88.3, 71.7, 78.3, and 94.1 responses/min for R1, R2, R5, and R6, respectively. The addition of the tandem IRT requirement uniformly decreased response rate; the respective values were 57.4, 44.2, and 30.5 responses/min for R1, R5, and R6 (recall R2 did not participate in the condition).

The filled symbols in the left column of Fig. 1 shows the maximum force exerted (peak force) for each response as function of position in the ratio. For all rats, peak force increased over the first several responses and decreased over the latter portion of the ratio; repeated measures ANOVAs identified a significant effect of response position for both schedules (FR10:  $F(9,27) = 4.0, p < 0.002$ ; FR20:  $F(19,57) = 13.4, p < 0.001$ ). Increasing the ratio requirement also had the effect of reducing maximal force in all animals. Averaging across the last six sessions, the mean (+SD) peak force (g) obtained under the FR 10 schedule was 24.5 (1.7), 25.5 (1.5), 22.0 (1.5), and 23.9 (1.0) for R1, R2, R5, and R6; the corresponding values from the FR 20 schedule were 18.7 (1.8), 15.7 (0.8), 12.5 (2.2), and 14.2 (0.7); the decrease in force is statistically significant (paired *t*-test,  $t = 8.9, df = 3, p < 0.001$ ).

Given the changes in peak force, it becomes natural to question how changes in peak force were related to total effort per sucrose delivery. Notterman and Mintz (1965) identified "effort" with the time integral of force measure, which is the sum of forces over the duration the response exceeds threshold, i.e., it is the area under the force-time curve (see also Brener and Mitchell, 1989). For the FR 10 schedule, the mean (+SD) time integral of force (g-s) per sucrose delivery was 428.2 (61.4), 528.3 (41.3), 568.2 (65.5), and 709.5 (90.1) for R1, R2, R5, and R6, respectively; values for the FR 20 component were 729.2 (100.7), 681.2 (79.2), 722.3 (121.8), and 1383 (219.8) for R1, R2, R5, and R6, respectively. The increase in time integral of force is statistically significant (paired *t*-test,  $t = -2.6, df = 3, p < 0.04$ ). Although the nominal response count was doubled for all animals, total effort changed only a small fraction for R2 and R5, while R1 and R6 experienced increases on order of 70–95%.

The right column of Fig. 1 shows interresponse time as a function of response position; the data are presented as logarithms to accommodate the variability observed across the study. Note, there is no IRT for the first response in the sequence, so no data point appears. In general, IRTs decreased as the ratio was completed, reflecting acceleration in responding across the ratio. We reasoned that the acceleration in response execution could work against increases in force, accounting for the decrease in response force across the ratio, and implemented the tandem IRT > t requirement; the results are shown in the open symbols in both columns of Fig. 1. Note, to keep the data presentation comparable across graphs, the data for the tandem schedule shows mean peak forces from the first 19 responses of the FR schedule and the terminal response of the IRT > t requirement; responses resetting the IRT > t requirement are dealt with separately below.

Download English Version:

<https://daneshyari.com/en/article/8497304>

Download Persian Version:

<https://daneshyari.com/article/8497304>

[Daneshyari.com](https://daneshyari.com)