Behavioural Processes 167 (2019) 103920

Contents lists available at ScienceDirect

Behavioural Processes

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

Control of response duration by delayed reinforcers: A systematic replication

Tom Byrne*

Massachusetts College of Liberal Arts, United States

ARTICLE INFO

Keywords:
Response duration
Delayed reinforcement
Rats
Lever pressing
Extinction

ABSTRACT

Three rats responded under schedules of delayed reinforcement in which sweetened condensed milk delivery depended upon lever-press durations exceeding or falling under a programmed value. For all rats, response durations increased compared to those emitted under a fixed-ratio 1 schedule when unsignaled delayed reinforcers were programmed for lever-press durations exceeding 1 s. For two of the rats, response durations also decreased when delayed reinforcer delivery was programmed for durations less than 1 s. Extinction reduced response rate, but did not affect response duration. Data suggest that the rate decreasing effects of unsignaled delayed reinforcers may be separated from the effects those reinforcers have on a targeted continuous dimension.

1. Introduction

Lever-press duration, the time between depression and release of a response lever, will increase if reinforcer delivery follows durations exceeding a specified value and not others (Platt et al., 1973; Kuch, 1974; Lachter and Corey, 1982). Recently, Byrne and Sarno (2018) reported that the duration of lever presses by rats increased when reinforcers delayed by 8 s followed lever presses of durations of 2 s or greater. Reinforcement delays were unsignaled, and any lever presses that occurred during the delay intervals postponed reinforcement delivery by 8 s. Resetting delays tend to drive down rates of discrete responding (Wilkenfield et al. (1992), and such findings were reported by Byrne and Sarno (2018). They proposed that arranging reinforcer delivery contingent upon response duration may provide an advantage over discrete responding for studying the effects of delayed reinforcement, because it may be possible to record increases in duration even when reinforcement delays drive down rates of discrete responding. When rate of discrete responding is the main dependent measure, decreases in response rate may make the effects of long reinforcement delays indistinguishable from behavior maintained by response-independent food delivery (Lattal, 2010).

The current study was designed to systematically replicate the procedures described by Byrne and Sarno. We had three goals. The first was to test if response duration was sensitive to reinforcement delays greater than 8 s. The second goal was to test if we could replicate the findings showing that delayed reinforcement can increase duration under the same conditions that reduce response rates. Finally, we wanted to test how extinction might affect both duration and response rate as little is known regarding the effects of extinction on continuous dimensions of behavior.

2. Method

2.1. Subjects

Three male Sprague Dawley rats (Taconic Biosciences, Hudson, NY), approximately 13 months old at the start of the study, served as subjects. All rats had previous experience responding under schedules in which reinforcers were delivered contingent upon lever presses of durations of anywhere from 0.5 to 10 s. Rats were group housed with unlimited access to water. They were maintained at 90% of their free feeding weights and kept under a12:12 h light/dark cycle. Procedures were approved by the Institutional Animal Care and Use Committee at Massachusetts College of Liberal Arts.

2.2. Apparatus

Three operant test chambers (Med Associates, St. Albans, VT) described elsewhere (Peck and Byrne, 2016) were used. Sweetened condensed milk (SCM) (Casa Solana Brand, Sysco Corporation, Houston, Texas) was provided by a liquid dipper.

2.3. Procedure

All sessions were 45 min in length and held at approximately the same time, five days per week. Sessions began with the illumination of

* Corresponding at: Department of Psychology, MCLA, 375 Church St, N. Adams, MA, 01247, United States.
E-mail address: t.byrne@mcla.edu.

https://doi.org/10.1016/j.beproc.2019.103920
Received 16 April 2019; Received in revised form 25 July 2019; Accepted 29 July 2019
Available online 30 July 2019

the house light and presentation of one response lever. Reinforcers consisted of 3 s of access to SCM. Rats were first exposed to a fixed-ratio (FR) 1 schedule in which each lever press resulted in immediate delivery of SCM. Response durations were recorded, but had no programmed consequence. In the following phase (Duration ≥ 1 Delay 16), any press in which the duration between depressing and releasing the lever met or exceeded 1 s initiated a 16-s delay interval which was followed by SCM delivery. Any lever-press duration less than 1 s that occurred during the delay cancelled any upcoming reinforcer delivery. Any lever-press greater than 1 s that occurred during the delay, reset the interval in what was essentially a differential reinforcement of other behavior procedure. In this arrangement, there was always at least 16 s between lever release and reinforcer delivery. In addition, the duration of the last press followed by reinforcer delivery had to be equal or greater to 1 s. For Rats 2 and 3, the third phase (Duration < 1 Delay 16), was similar to the prior phase, except that lever-press durations had to be less than 1 s to initiate the delay interval. Lever-press durations less than 1 s emitted during the reinforcement delay reset the interval. Lever press durations greater than 1 s during the delay cancelled the upcoming reinforcer. Prior to this phase, Rat 1 only was exposed to conditions in which presses of any duration started and reset the delay interval. It quickly become evident that this arrangement produced few opportunities for differential reinforcement, and it was not implemented for Rats 2 and 3. Following exposure to the Duration < 1 Delay 16 phase, all rats were exposed again to the Duration ≥ 1 Delay 16 condition. Finally, all rats were exposed to extinction in which lever pressing was recorded but resulted in no programmed consequences.

3. Results

Fig. 1 depicts the percent of lever presses that equaled or exceeded 1 s in duration and the durations in the 90th percentile for each session. We chose to plot the longest durations, as prior research suggests that shorter durations tend to be invariant regardless of the reinforcement contingencies (Byrne and Sarno, 2018). Durations increased over 300, 600, and 500 percent for Rats 1, 2, and 3, respectively, between the last session of FR 1 exposure and the first session of Duration ≥ 1 Delay 16. For Rats 2 and 3, durations decreased gradually but substantially during the Duration < 1 Delay 16 phase. For Rat 1, there were no appreciable changes in response duration in any of the conditions following the first Duration ≥ 1 Delay 16 phase. For Rats 2 and 3, the reversal to the Duration ≥ 1 Delay 16 condition resulted in increases in response durations, however the effects were smaller than those observed during the first exposure. For both rats, there was an increase of over 100% in the number of lever presses greater than 1 s during the first session of the Duration ≥ 1 Delay 16, and durations in the 90th percentile for both rats exceeded those recorded during the last 10 sessions of the Duration < 1 Delay 16 phase. During extinction, durations increased for Rats 2 and 3, and the percent of lever presses greater than 1 s remained unchanged for Rats 1 and 2 and increased for Rat 3.

Fig. 2 depicts overall response rates for each session. Delayed reinforcement combined with duration requirements decreased response rates for all rats compared to those recorded under the FR 1 condition, but there was no consistent difference in response rates when comparing the Duration ≥ 1 Delay 16 vs. Duration < 1 Delay 16 phases. Response rates decreased during extinction for all rats.

4. Discussion

Lever-press durations increased when reinforcers delayed by 16 s were contingent upon lever press durations exceeding a programmed value. Thus, the answer to the main question of the study, whether response duration is sensitive to reinforcement delays longer than those reported by Byrne and Sarno (2018), appears to be yes.

The second goal of the study was to further investigate Byrne and Sarno's proposal that arranging delayed reinforcers for lever holding may still result in measurable increases in duration even if the number of discrete responses decreases. The current data provide some support for this assertion in that 16-s reinforcement delays, which were contingent upon response durations greater than 1 s, increased duration while response rates decreased simultaneously compared to those observed under the FR 1 schedule. Thus, delayed reinforcement may increase one dimension of behavior while reducing another.

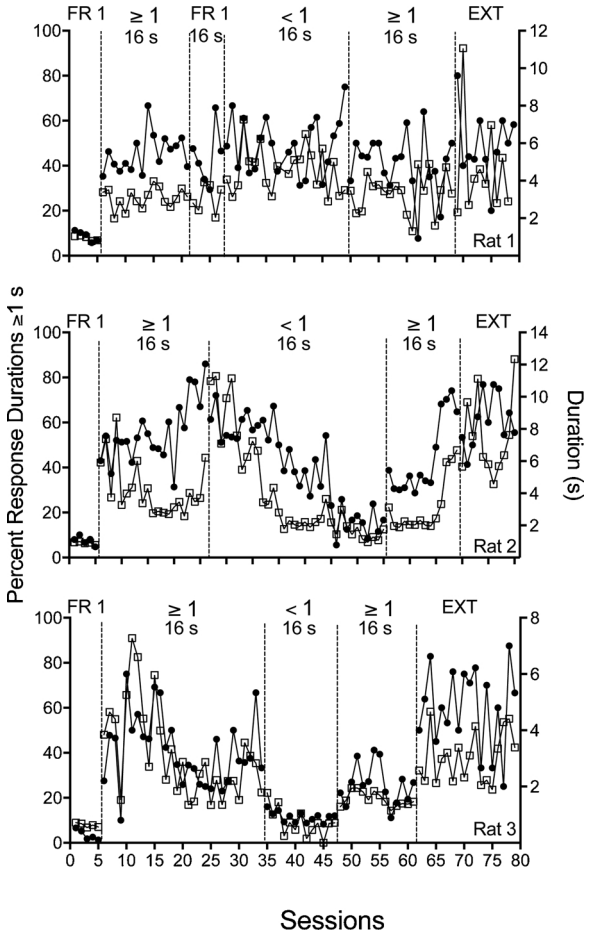

Fig. 1. Percent of lever presses greater than 1 s (circles and left y-axis) and duration of responses in the 90th percentile (squares and right y-axis) for all sessions.

The third goal of the study was to test the effects of extinction on both response duration and response rate. The effects of extinction were difficult to interpret and require further experimentation. For all three rats, response rates declined during extinction. However, response durations did not decrease for Rats 1 and 2 and increased for Rat 3 even when few lever presses occurred during the final sessions of the extinction phase. Early investigations reported that durations of lever presses increased during extinction in rats with a history of responding under reinforcement schedules in which reinforcers were arranged for discrete responses of any duration, although maximum durations were much shorter than those we found, with responses rarely exceeding 1 s and none reported greater than 2 s (Hurwitz, 1954; Margulies, 1961). If extinction increases lever-press duration, even in rats without a history of duration-contingent reinforcement, caution is needed in interpreting the effects of delayed reinforcers on response duration as increases in duration requirements may lead to unreinforced short-duration responses. This confound was partially overcome in the current study by arranging delayed reinforcers contingent on both increases and decreases in response duration, with bi-directionality in response duration demonstrated in two out of the three rats.

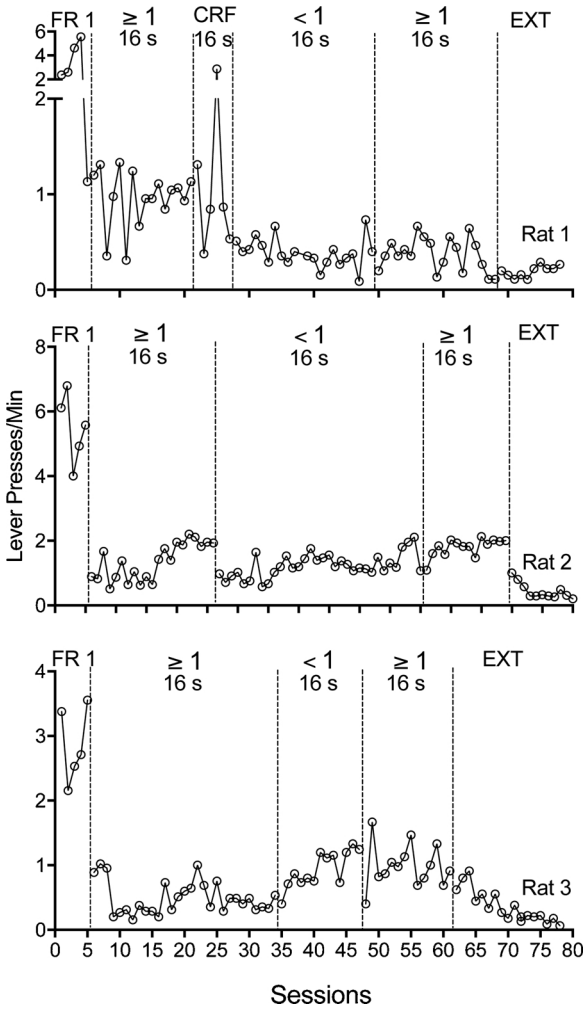

Fig. 2. Response rate for all sessions.

It is possible that resurgence played a role in facilitating satisfaction of the reinforcer requirement during the transition between the first two phases. Resurgence involves the recurrence of some dimension of a behavior when conditions of reinforcement for more current behavior are worsened (Lattal et al., 2017). Typically, resurgence is demonstrated when a previously-reinforced operant (e.g. pressing Lever A) increases in rate when a more recently reinforced and topographically-distinct alternative behavior (e.g. pressing Lever B) is placed on extinction (Doughty and Oken, 2008; Epstein, 1983). In the current study, there was a similar reinforcement history, except that we arranged differential reinforcement of response duration on a single operandum. Prior to the current study, all rats had learning histories in which response durations of greater that 1 s contacted reinforcement. So, when shorter durations contacted extinction during the onset of the Duration ≥ 1 Delay 16 condition, a resurgence of longer response durations may have facilitated contact with reinforcement. Benavides and Escobar (2017) reported evidence of resurgence of response duration in human participants, so this dimension of behavior can reemerge during extinction. The current data provide preliminary evidence that resurgence of response duration can also occur in nonhumans.

In conclusion, the current data provide further evidence that delayed reinforcement may affect continuous dimensions of behavior. By arranging food delivery for response duration, it was possible to measure an increase in behavior even when resetting reinforcement delays decreased response rate. Response duration has received relatively little attention as a dependent measure as compared to rates of discrete responding, and adding this dimension to analyses may provide additional information about basic learning processes.

References

Benavides, R., Escobar, R., 2017. Resurgence of response duration in human participants. Behav. Processes 142, 106–109. https://doi.org/10.1016/j.beproc.2017.06.010.

Byrne, T., Sarno, B., 2018. Response duration is sensitive to both immediate and delayed reinforcement. J. Exp. Anal. Behav. 111 (1), 94–115. https://doi.org/10.1002/jeab.491.

Doughty, A.H., Oken, G., 2008. Extinction-induced response resurgence: a selective review. Behav. Anal. Today 9 (1), 27–33. https://doi.org/10.1037/h0100644.

Epstein, R., 1983. Resurgence of previously reinforced behavior during extinction. Behavior Analysis Letters 3, 391–397.

Hurwitz, H.M.B., 1954. Response-duration of lever pressing in the rat. Q. J. Exp. Psychol. 6 (2), 62–71. https://doi.org/10.1080/17470215408416650.

Kuch, D.O., 1974. Differentiation of press durations with upper and lower limits on reinforced values. J. Exp. Anal. Behav. 22 (2), 275–283. https://doi.org/10.1901/jeab.1974.22-275.

Lachter, G.D., Corey, J.R., 1982. Variability of the duration of an operant. Behav. Anal. Lett. 2 (2), 97–102.

Lattal, K.A., 2010. Delayed reinforcement of operant behavior. J. Exp. Anal. Behav. 93 (1), 129–139. https://doi.org/10.1901/jeab.2010.93-129.

Lattal, K.A., Cançado, C.R.X., Cook, J.E., Kincaid, S.L., Nighbor, T.D., Oliver, A.C., 2017. On defining resurgence. Behav. Processes 141, 85–91. https://doi.org/10.1016/j.beproc.2017.04.018.

Margulies, S., 1961. Response duration in operant level, regular reinforcement, and extinction. J. Exp. Anal. Behav. 4 (4), 317–321. https://doi.org/10.1901/jeab.1961.4-317.

Peck, S., Byrne, T., 2016. Demand in rats responding under duration-based schedules of reinforcement. Behav. Processes 128, 47–52. https://doi.org/10.1016/j.beproc.2016.04.002.

Platt, J.R., Kuch, D.O., Bitgood, S.C., 1973. Rats' lever-press durations as psychophysical judgements of time. J. Exp. Anal. Behav. 19, 239–250. https://doi.org/10.1901/jeab.1973.19-239.

Wilkenfield, J., Nickel, M., Blakely, E., Poling, A., 1992. Acquisition of lever-press responding in rats with delayed reinforcement: a comparison of three procedures. J. Exp. Anal. Behav. 58 (3), 431–443. https://doi.org/10.1901/jeab.1992.58-431.