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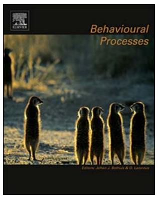

A comparison of resetting and nonresetting contingencies in progressive-duration schedules

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ABSTRACT

We compared two progressive schedules of reinforcement in which rats received access to sweetened condensed milk for depressing and holding down a response lever. Duration requirements increased after each reinforcer delivery in a manner similar to progressive-ratio schedules. Under one schedule, any response duration less than that required for reinforcement had no programmed consequences. Under the second schedule, the cumulative duration of all responses could meet the reinforcement criteria. Breaking points were consistently higher when all lever presses, regardless of duration, contributed to meeting the reinforcer requirements. Breaking points under both schedules increased when food deprivation was long enough to result in body-weight reductions, but the sensitivity of the schedules to brief periods of food deprivation was inconsistent. Under both schedules, food deprivation produced an increase in shorter durations, thus reducing the efficiency of responding.

1. Introduction

Data from two recent investigations indicate that response duration is sensitive to motivating operations. Bailey et al. (2015) described a "progressive hold-down" procedure with mice, in which edible reinforcer delivery was contingent upon the depression of a lever for a programmed duration. Duration requirements increased after every reinforcer delivery in a fashion similar to progressive-ratio (PR) schedules (Hodos, 1961). Sessions ended after responding ceased for a specified amount of time. As is also done with progressive-ratio schedules, Bailey et al. reported breaking points as a key dependent measure. These were the highest reinforcement criteria met during each session. Breaking points appeared sensitive to both food-deprivation levels and the sucrose-concentration of the reinforcer. Gulotta and Byrne (2015) investigated a similar duration-based schedule of reinforcement in rats responding for sweetened condensed milk, and likewise found that breaking points were sensitive to motivating operations.

Schedules of reinforcement in laboratory investigations of operant behavior have historically been arranged for studying response rate rather than continuous measures of behavior such as duration (Williams and Johnston, 1992). Response duration has received little attention in the laboratory (for exceptions see Kuch, 1974; Platt et al., 1973; Lachter and Corey, 1982; Senkowski et al., 1978; Stevenson and Clayton, 1970). 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., 2008; Williams and Johnston, 1992).

Compared to their ratio-based counterparts, duration-based progressive schedules may present some interpretation challenges. As typically arranged, reinforcers under a PR schedule are delivered as soon as the current ratio requirement is completed. Therefore, as long as inter-response times (IRTs) do not exceed the experimenter-designated breakpoint criteria, each discrete response (i.e. a lever press) counts towards meeting reinforcement requirements. However, under the procedures utilized by both Bailey et al. (2015) and Gulotta and Byrne (2015), any press in which the subjects released the lever prior to the completion of the duration requirement was not counted towards meeting the reinforcement criteria. Therefore any sub-criteria durations were essentially wasted effort. Because such responses contact extinction, it is possible that such resetting contingencies suppress responding. There is also a further complication. When reinforcement is arranged for lever holding of fixed durations, rats will often emit many responses which are too short to meet reinforcement criteria (Kuch, 1974; Lachter and Corey, 1982; Senkowski et al., 1978; Peck and Byrne, 2016), and food deprivation may increase the prevalence of these sub-criteria durations. Senkowski et al. (1978) trained rats to depress a response lever for fixed durations of between 0.4 and 7.6 s. They found that increasing the level of food deprivation increased variability and decreased mean response duration. If behavior maintained under the types of progressive-duration schedules reported by Bailey et al. (2015) and Gulotta and Byrne (2015), are affected similarly by food

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deprivation, then motivational operations could have oppositional effects on breaking points. Deprivation may alter the reinforcing efficacy of food while engendering higher proportions of response durations too short to contact reinforcement contingencies. It is possible this could limit the sensitivity of these procedures.

To our knowledge there have been no investigations of progressive-duration schedules in which all responses, regardless of duration, contribute cumulatively to meeting reinforcer requirements. The primary objective of the current study was to compare two types of progressive-duration schedules. In one, sub-criteria responses had no programmed consequences. In the other, reinforcers were delivered for cumulative durations which could be amassed over any number of discrete lever presses. We hypothesized that this arrangement may be more resistant to any increases in short-duration responding that might be evoked by food deprivation. To see if motivating operations (Michael, 1982, 2000; Laraway et al., 2003) affected breaking points under each variant, we tested the effects of both 24 h food-deprivation probes and chronic food restriction.

2. Methods

2.1. Subjects

Eight male Long-Evans rats, approximately 15 months of age at the start of the study, served as subjects. All rats had prior lever-pressing experience under a progressive-

duration schedule identical to the resetting condition described below. Rats were housed in groups of four with unlimited access to food and water and were subject to 12:12 h light/dark cycle.

2.2. 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 retractable 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 (Casa Solana Brand, Sysco Corporation, Houston, Texas) 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-attenuation boxes equipped with a fan to provide ventilation and sound masking. A house light was illuminated during all sessions. All environmental events were controlled by a microcomputer running MED-PC software (MED Associates, St. Albans, VT) located in an adjacent room. Jumper switches were set on the interface module to allow for continuous polling of the lever position.

2.3. Procedures

All sessions began with the illumination of the house light and presentation of one response lever. All reinforcers consisted of three seconds of access to sweetened condensed milk. Under all conditions, the first reinforcer of each session was delivered immediately upon depression of the response lever. An ABAB (A = resetting, B = nonresetting) design was used to test both resetting and nonresetting conditions. Under the resetting condition, each subsequent reinforcer was delivered for depressing the lever for a duration that increased by 0.5 s after each reinforcer delivery. Any response of a duration less than that required for reinforcer delivery reset the duration timer, and no reinforcer was delivered. Under the nonresetting condition, reinforcer requirements progressed in the same fashion, except the duration of every lever press contributed to the duration requirements in a cumulative fashion. For example, three individual presses with durations of 1, 4, and 5 s would meet a reinforcer requirement of 10 s in the nonresetting condition. In the resetting condition, only a single press that was 10 s in duration would meet a 10-s reinforcer requirement. Under both conditions, sessions ended when no reinforcers were earned for 10 min. The highest duration requirement met before the termination of each session was recorded as the breaking point. Each of the first three phases was kept in place for a minimum of 10 sessions and until no trends were noted using visual analysis. The fourth phase was 5 sessions for all rats. We arranged a food-deprivation probe for the final session of the second and third phases. Rats were placed on 24 h of food deprivation prior to this session. Following the food-deprivation probes, rats were immediately placed back on free feed in their home cages.

Following the second nonresetting condition (phase 4), rats were placed on a restricted diet of 5 g of food per day. During this food-restriction phase, Rats 1, 3, and 7 were exposed to the resetting condition, and Rats 2, 4, 6, and 8 were placed under the nonresetting condition. The phase ended the first session after rats dropped to 90% or less of their free-feeding weight. Rats were then placed back on free-feed in their home cages. The final phase started the next day, and rats performed under the same conditions as in the previous phase. Rat 5 was excluded from the final two phases due to health concerns. Data from the final session for Rat 4 was lost due to a corrupted data file.

3. Results

Breaking points are depicted in Fig. 1. For all rats, breaking points were higher overall under nonresetting versus resetting conditions. For Rats 3 and 4, the increase in breaking points between the first and second phase was slight or absent, but breaking points decreased during the reversal in the third phase. For all rats except Rat 6, breaking points clearly increased during the second exposure to the nonresetting contingency. In addition, because data from all sessions of the second exposure to the nonresetting contingency are included, a level change is evident during the first session of this phase for all rats except Rat 6.

Effects of the food-deprivation probes during the second and third phases were inconsistent. For Rats 1, 3, and 4, 24 h of food deprivation were followed by the highest breaking points in both the resetting and nonresetting conditions. For Rats 2, 6, and 8, breaking points following the food-deprivation probes were higher than phase means, but lower than at least one other data point within their respective phase. There was no noticeable effect of 24 h of food deprivation on breaking points for Rats 5 and 7.

Restricting post-session feedings to 5 g reduced weights for all rats. Over the course of this phase, Rat 1′s weight fell from 545 to 508 g, Rat 2′s weight fell from 518 to 496 g, Rat 3′s weight fell from 572 to 528 g, Rat 4′s weight fell from 482 to 536 g, Rat 6′s weight fell from 613 to 542 g, Rat 7′s weight fell from 544 to 505 g, and Rat 8′s weight fell from 616 to 578 g. For all rats except Rat 7, breaking points increased under the food-restriction phase. During this phase, Rats 1, 3, and 7 responded under resetting conditions, so the appropriate comparisons should be made with phases 1 and 3. For Rat 7, breaking points under food deprivation were higher compared with phase 3, but not phase 1. Rats 2, 4, 6, and 8 responded under nonresetting conditions during this phase, so comparisons should be made with phases 2 and 4. For all rats, breaking points decreased once they were returned to free feed in the final phase, and a level drop was evident during the first session of the phase.

Fig. 2 depicts all discrete lever presses for all rats in each phase. In general, the effects of the resetting versus the nonresetting condition on the number of lever presses were similar to the effects on breaking points, with more pressing evident under the nonresetting conditions. This effect was minimal in Rats 2, 4, and 6. The effects of food-deprivation probes in the second and third phases was inconsistent, with increases in lever pressing in both phases evident in Rats 3 and 4 only.