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Short communication

Effects of past and upcoming response-force requirements on fixed-ratio pausing

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Abstract

Four rats obtained food by pressing a lever 30 times in each component of a two-component multiple schedule. Across conditions, the force required to press the lever was increased in one component and held constant in the other. Pausing at the outset of each component was controlled by both the past and upcoming force requirements: Pauses were longer when the upcoming requirement was high and this effect was intensified when the past requirement was low. In concert with previous research, the results support the general proposition that behavior is disrupted by abrupt, discriminable transitions from favorable to unfavorable schedule conditions, across a range of subjects and operational definitions of favorability.

Keywords: Escape; Fixed ratio; Food deprivation; Multiple schedule; Pause; Response effort

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1. Introduction

Fixed-ratio (FR) schedules are characterized by an absence of responding immediately following consumption of the reinforcer (Ferster and Skinner, 1957). The duration of this pause is affected by the schedule conditions of the immediate past and stimuli correlated with upcoming conditions. Perone and Courtney (1992) exposed pigeons to a compound schedule with irregularly alternating components. Completing an FR requirement led to a small reinforcer (2-s access to grain) in one component and to a large reinforcer (6-s) in the other component. Pauses were analyzed according to four types of transitions between past and upcoming schedules: the transition from an unfavorable schedule (with a small reinforcer) to another unfavorable schedule, from an unfavorable schedule to a favorable schedule (with a large reinforcer), from favorable to unfavorable, and from favorable to favorable.

In some of Perone and Courtney's (1992) conditions the components were accompanied by distinctive stimuli (i.e., a multiple schedule operated). Under these conditions, pausing was a joint product of the past and upcoming schedule conditions. Pauses were brief

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when the upcoming conditions were favorable. When the upcoming conditions were unfavorable, however, pausing depended on the favorability of the past conditions, with brief pauses after unfavorable conditions and extended pauses after favorable conditions. This joint control was absent under mixed-schedule conditions when no stimuli accompanied the upcoming schedule components.

The present experiment investigated the generality of the disruptive effect of the transition from favorable to unfavorable schedule conditions. In comparison with Perone and Courtney (1992), we studied rats instead of pigeons and, more importantly, we defined favorability in terms of response effort rather than reinforcer magnitude. Several studies have reported preference for a low-effort alternative in a choice situation (Keehn, 1981; Miller, 1968; Sumpter et al., 1998). Therefore, low and high effort requirements comprised the favorable and unfavorable conditions, respectively.

2. Materials and methods

2.1. Subjects

Four adult male Sprague–Dawley rats, each experienced with FR schedules and various response-force requirements, were maintained at 80% (±2%) of their predicted free-feeding body weights using a procedure like that described by Davenport and Goulet (1964). The rats were housed individually under a 12:12 h reversed light/dark cycle.

2.2. Apparatus

Four identical operant chambers with interior dimensions of 29 cm × 22 cm × 24 cm (length × height × depth) were enclosed in ventilated, sound-attenuating cubicles. Illumination was provided by a low-wattage bulb. On the front wall were two retractable levers, which could protrude 1.9 cm into the chamber, and two white cue lights positioned approximately 5 cm above each lever. The force required to press the spring-loaded levers was adjusted manually using calibration weights. Centered on the front wall was a magazine into which food pellets (45 mg, Research Diets) were dispensed. A photocell detected the rat's head in the magazine. White noise (85 dB) masked extraneous sounds. Experimental events were controlled and recorded using Med-PC for Windows software and interfacing.

2.3. Procedure

Throughout the experiment, a multiple FR 30 FR 30 schedule operated. This ratio size was selected because it was the maximum at which responding could be maintained with the present procedure. Each component was associated with its own lever, and only that lever was inserted while the component was underway. Sessions began with the onset of white noise and the insertion of either the left or right lever, depending on the component in effect. The cue light above the lever was illuminated. Lever presses meeting the minimum force requirements (described below) produced 0.1-s offset of the cue light. When reinforcement was due, the lever retracted, the noise turned off, a relay click sounded, and a pellet was delivered into the food magazine. The reinforcement cycle ended 2 s after the rat's head entered the magazine, at which point the next component began with the onset of the white noise, insertion of the appropriate lever, and illumination of the appropriate cue light.

In each session, 41 components comprised a semi-random sequence that allowed 10 exposures to each possible transition between low- and high-force requirements: from a low-force component to another low-force component (favorable-to-favorable), from low-force to high-force (favorable to unfavorable), from high-force to low-force (unfavorable-to-favorable), and from high-force to another high-force (unfavorable to unfavorable). Details of the component sequencing are in Perone and Courtney (1992).

During an initial baseline condition, both levers required 0.25 N of force to operate. Across subsequent conditions, the requirement on one lever (the high-force lever) was increased in steps of 0.15 N, whereas the requirement on the other lever (the low-force lever) remained constant at 0.25 N. The designation of the low- and high-force levers was based on each rat's history with a similar procedure. The lever that previously had a high-force requirement was designated the low-force lever and the other was designated the high-force lever.

After a minimum of 20 sessions per condition, the stability of pausing was judged by calculating medians over a moving window of the most recent 10 sessions.

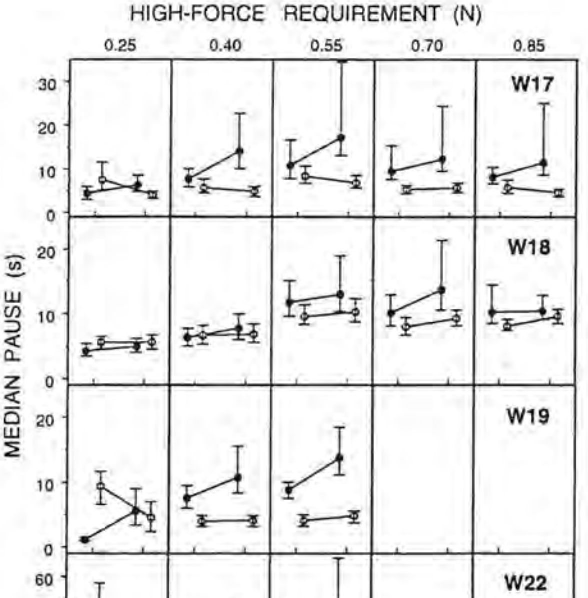

Fig. 1. Median pause durations as a function of past and upcoming force requirements over the last 10 sessions of each condition. The error bars represent the interquartile ranges (25th to 75th percentiles).

Over the last five windows (e.g., for sessions 7–16, 8–17, 9–18, 10–19, and 11–20), the median pause in each transition had to be free of upward or downward trend. In some cases, a condition was ended after a rat failed to complete a session within 2 h over several consecutive days.

3. Results and discussion

Because the distribution of pausing was positively skewed, the median was selected as the measure of central tendency. Fig. 1 shows median pauses and interquartile ranges in each transition based on the last 10 sessions of each condition. When the force requirement in both components was 0.25 N, two rats (W17 and W18) paused for similar durations in the four transitions, but the other two (W19 and W22) paused longer in what is labeled the high- to low-force transition. This likely was the result of the rats' histories: the lever selected as the low-force lever in the present experiment had been the high-force lever in a previous experiment. Given that history, it is not surprising that, during baseline, pausing was extended in what formerly was a low-to-high transition.

When the high-force requirement was increased to 0.40 N, rats W17, W19, and W22 paused longer in the high-force component. In addition, pauses were extended in the low-to-high (i.e., the favorable to unfavorable) transition. When the high-force requirement was increased to 0.55 N, pauses increased in the transitions to high force, and pauses in the transitions to low force increased or remained the same.

Rats W17 and W18 completed conditions in which the high-force requirement was increased above 0.55 N. At 0.70 N, pauses in the low-to-high transition decreased (but remained longer than in the other transitions). Increasing the requirement to 0.85 N induced no further change.

Whereas the pausing in the low-to-high transition peaked at 0.55 N for W17, it peaked at 0.70 N for W18. At 0.85 N, extended pausing in the low-to-high transition was no longer observed for this rat. The reason is unclear.

Fig. 2 shows median running response rates (responses divided by the time between the first response and reinforcement) and interquartile ranges based on the last 10 sessions of each condition. During baseline, all rats responded at higher rates on the lever designated the high-force lever, even though both levers required 0.25 N to operate. Again, this is likely the result of the rat's history with a low-force requirement on the lever designated the high-force lever in the present experiment. When the requirement increased to 0.40 N on this lever, run rates dropped below those on the low-force lever, and this difference was maintained across the remaining conditions. This result is consistent with previous research showing an inverse relation between the response-force requirement and response rates on FR schedules (Alling and Poling, 1995). Nonetheless, there were variations in the difference in rates: Rat W17's low-force responding increased as the high-force requirement was raised from 0.55 to 0.70 to 0.85 N, while Rat W18's high-force responding decreased when the requirement was raised from 0.40 to 0.55 N. There was a tendency for rates to

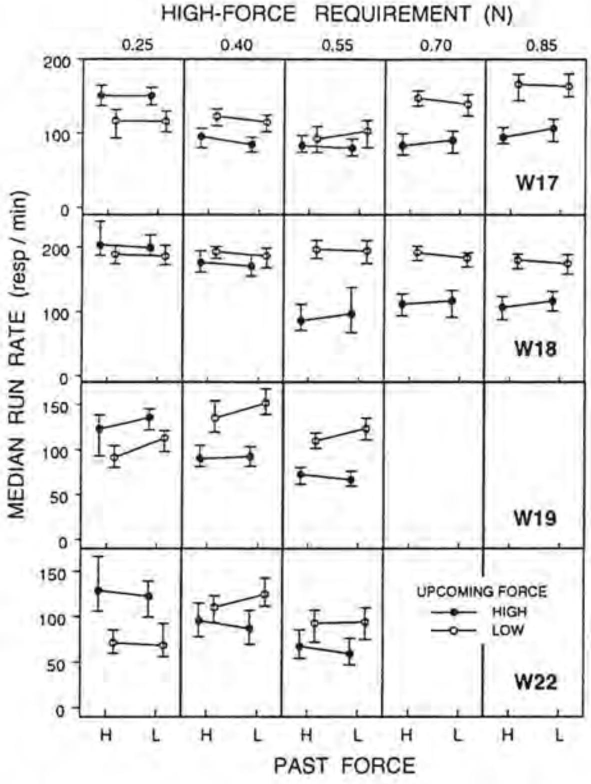

Fig. 2. Median run rate (responses per min) as a function of past and upcoming force requirements over the last 10 sessions of each condition. The error bars represent the interquartile ranges (25th to 75th percentiles).

be lowest in the low-to-high transition, but the effect was small and inconsistent within and between rats.

The major finding, then, is that at several levels of the response-force parameter, rats' pauses were longest in the transition from a schedule requiring presses on a low-force lever to one requiring presses on a high-force lever. Also, in some cases, pausing in the low-to-high transition increased with increases in the high-force requirement. Despite the lack of a return to baseline, this effect cannot be explained solely by order effects, as similar changes in pausing were not evident in the other transitions (particularly in the high-to-high transition). These results replicate Perone and Courtney's (1992) observation that pigeons paused for an extended duration in the transition from a schedule ending in 6-s access to mixed grain to one ending in 2-s access, and Bejarano et al.'s finding that an adult with mental retardation paused longest in a transition from a low ratio ending in \$0.25 to a high ratio ending in \$0.01. Taken together, these findings support the general proposition that operant behavior is disrupted by discriminable shifts from favorable to unfavorable schedule conditions—regardless of whether the subjects are rats, pigeons, or people, and whether favorability is operationalized in terms of response-force, duration of access to food, or a combination of response requirements and the size of monetary reinforcers.

What function is served by pausing in the favorable to unfavorable transition? Perhaps the transition is aversive and the interruption in responding measured as pausing is a form of escape. Azrin (1961) gave pigeons the option of pecking an escape key to initiate a timeout from an FR schedule. Because the birds did escape, Azrin (1961) concluded that schedules of positive reinforcement have aversive aspects. Other research has shown that animals will escape from FR schedules (Appel, 1963; Ator, 1980; Thompson, 1964), fixed-interval (FI) schedules (Brown and Flory, 1972; Cohen and Campagnoni, 1989), and progressive-ratio schedules (Dardano, 1973). These studies also report that escape occurred during the period typically associated with pausing, that is, in the period immediately following receipt of the reinforcer. Further evidence of the functional similarity of pausing and escape comes from studies showing that both variables are directly related to increases in FR (Azrin, 1961; Appel, 1963; Thompson, 1964) and FI parameters (Brown and Flory, 1972; Cohen and Campagnoni, 1989).

Because transitions from favorable to unfavorable conditions are ubiquitous, it is likely that they play a role in the development of many counterproductive behaviors exhibited by people outside the laboratory (Bejarano et al., 2003), for example, in occupational and academic settings. From an occupational standpoint, the transitions involving high effort are noteworthy. Paradoxically, arranging a break from the high-force lever made it more difficult for the subjects to resume work on that lever: In 11 of the 12 conditions in which the force requirements differed on the two levers, responded was disrupted less (i.e., pausing was briefer) in the high- to high-force transition than in the low- to high-force transition. The potential relevance of such effects to real-world situations invites additional research investigating ways to modulate the disruption induced by transitions between task demands that vary in favorability.

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References

Alling, K., Poling, A., 1995. The effects of differing response-force requirements on fixed-ratio responding of rats. J. Exp. Anal. Behav. 63, 331–346.

Appel, J.B., 1963. Aversive aspects of a schedule of positive reinforcement. J. Exp. Anal. Behav. 6, 423–428.

Ator, N.A., 1980. Mirror pecking and timeout under a multiple fixed-ratio schedule of food delivery. J. Exp. Anal. Behav. 34, 319–328.

Azrin, N.H., 1961. Time-out from positive reinforcement. Science 34, 382–383.

Bejarano, R., Williams, D.C., Perone, M., 2003. Pausing on multiple schedules: toward a laboratory model of escape-motivated behavior. Exp. Anal. Human Behav. Bull. 21, 18–20.

Brown, T.G., Flory, R.K., 1972. Schedule induced escape from fixed-interval reinforcement. J. Exp. Anal. Behav. 17, 395–403.

Cohen, P.S., Campagnoni, F.R., 1989. The nature and determinants of spatial retreat in the pigeon between periodic grain presentations. Anim. Learn. Behav. 17, 39–48.

Dardano, J.F., 1973. Self-imposed timeouts under increasing response requirements. J. Exp. Anal. Behav. 19, 269–287.

Davenport, D.G., Goulet, L.R., 1964. Motivational artifact in standard food-deprivation schedules. J. Comp. Physiol. Psychol. 57, 237–240.

Ferster, C.B., Skinner, B.F., 1957. Schedules of Reinforcement. Appleton-Century-Crofts, New York.

Keehn, J.D., 1981. Choice of equal effects with unequal effects: a way to quantify the law of least effort. Bull. Psychon. Soc. 17, 166–168.

Miller, L.K., 1968. Escape from an effortful situation. J. Exp. Anal. Behav. 11, 619–627.

Perone, M., Courtney, K., 1992. Fixed-ratio pausing: joint effects of past reinforcer magnitude and stimuli correlated with upcoming magnitude. J. Exp. Anal. Behav. 57, 33–46.

Sumpter, C.E., Temple, W., Foster, T.M., 1998. Response form, force, and number: effects on concurrent-schedule performance. J. Exp. Anal. Behav. 70, 45–68.

Thompson, D.M., 1964. Escape from SD associated with fixed-ratio reinforcement. J. Exp. Anal. Behav. 7, 1–8.