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PAUSES IN MULTIPLE EXTINCTION FIXED-INTERVAL REINFORCEMENT SCHEDULES WITH FIXED DURATIONS OF THE EXTINCTION COMPONENT: IMPLICATIONS FOR TIMING

PAUSAS DURANTE PROGRAMAS MÚLTIPLES DE REFORZAMIENTO EXTINCIÓN-INTERVALO FIJO: IMPLICACIONES PARA LA ESTIMACIÓN TEMPORAL

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Abstract

Five rats served in an experiment with multiple extinction fixed-interval schedules of reinforcement. While the fixed-interval schedule was kept constant at 60 s, the fixed extinction period was varied from 10 to 160 s. Pauses during the fixed-interval schedule decreased systematically with increases in the previous extinction period. Pausing was under control of both time to the next primary reinforcement signaled by the discriminative stimulus associated with the fixed-interval schedule and time since the last primary reinforcement, signaled by the duration of the extinction period.
Keywords: pauses, multiple extinction fixed-interval schedules, timing, rats

Resumen

Se usaron cinco ratas en un experimento con programas múltiples de reforzamiento extinción-intervalo fijo. Mientras que el programa de intervalo fijo se mantuvo constante en 60 segundos, el período fijo de extinción se varió desde 10 a 160 segundos. Las pausas durante el programa de intervalo fijo disminuyeron sistemáticamente con

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los aumentos en la duración del periodo de extinción previo. Las pausas estuvieron bajo el control de ambos, el tiempo al siguiente reforzador primario señalado por el estímulo discriminativo asociado con el programa de intervalo fijo y el tiempo desde el último reforzador primario, señalado por la duración del periodo de extinción.

Palabras clave: pausas, programas múltiples de reforzamiento extinción-intervalo fijo, estimación temporal, ratas

Timing, that is, the temporal control over behavior, has been an elusive but absorbing subject for behavior analysis (e.g., Baum, 2012; Machado, 1997; Lejeune, Richelle, & Wearden, 2006; Staddon & Cerutti 2003). Regularities in the presentation of reinforcers and in the relation of events to reinforcers are sources of temporal control. Staddon and Cerutti (2003) defined *interval timing* as the covariation of a dependent variable, for example, a pause in responding under fixed-interval (FI) schedules of reinforcement, and the length of the interval between reinforcement in that schedule (e.g., Aparício, Lopez, & Nevin, 1995; Dragoi, Staddon, Palmer, & Buhusi, 2003; Lejeune & Wearden, 1991; Lopez & Menez, 1999; Machado, 1997).

In FI schedules programmed singly, pauses represent around 50 to 60% of the size of interval before response acceleration. Postreinforcement pauses are attributed to the fact that stimuli associated with that period function as a signal for the absence of reinforcement of responses (Ferster & Skinner, 1957). In chained schedules when an FI schedule is the first component of the chain, pauses are extremely long (Kelleher & Fry, 1962, p. 172), but practically nonexistent when FI schedules are programmed as the terminal links in concurrent chains (e.g., Duncan & Fantino, 1970; Davison & Temple, 1974). These results are consistent with the interpretation of primary interreinforcement intervals (i.e., intervals between presentations of primary reinforcers) as the major determinant of pausing. Even in complex time schedules (e.g., Todorov, Carvalho, Couto, Cruz, & Cunha, 2012), any stimuli, either external or produced by the subject's own behavior, associated with postreinforcement periods, will inhibit responding as long as they endure. The absence of such stimuli signals the proximity of primary reinforcement. Data from chain FR FI (Todorov, et al., 2012; Todorov, Couto, & Carvalho, 2013), chain FI FI FI (Kelleher & Fry, 1962) and tandem FR FI (Shull, 1970) schedules show that the first component after primary reinforcement controls relatively long pauses and that responding tends to concentrate in the second (or last) component, with short or no pauses. A similar effect seems to occur in multiple schedules. Alternating periods of extinction with an FI schedule of reinforcement in a multiple schedule and using rats as subjects, de Rose (1986) found that increases in duration of the extinction component in probes within a session tended to decrease pause length in FI 18- and 30-s schedules. Todorov et al. (2012) investigated the behavior of rats in chain fixed-ratio (FR) x, FI 60-s schedules and found that as the FR requirement was increased, primary interreinforcement intervals (IRIs) increased and pauses in the FI schedule decreased. The present work was an extension of previous work by de Rose (1986) and Todorov et al. (2012) using a multiple schedule procedure in which an FI 60-s schedule was kept constant while the extinction component duration was varied from 10-s to 160-s in different conditions, with a stability criterion defining stability in each condition. The effect of extinction component duration was studied in stability, not in transition as in de Rose (1986), and the IRI was manipulated directly, as opposed to Todorov et al.'s (2012) indirect manipulation of the IRI.

Method

Subjects

Five naïve, male Wistar rats, six months old at the beginning of the experiment, were used. The rats were born and maintained in the vivarium of the Centro Universitário IESB, housed individually in polycarbonate cages (30 x 30 x 50 cm), and maintained on a 12 h/12 h light/dark cycle with constant temperature (20 ± 18°C) and relative humidity (55%). Food was available at all times, and access to water was restricted for 48 hrs before each experimental session.

Apparatus

MedAssociates Modular Test Chambers (MedAssociates ENV-008 SN: 3318) for rats were used (30 cm wide x 25.5 cm high x 25.5 cm deep). The chambers had two standard response levers located 7.5 cm from the floor, 13.5 cm from each other, and 1.5 cm from the chamber walls, and access to water controlled by an electromechanical device. Access to water was through an aperture 5 cm by 5 cm located centrally between the response levers. During reinforcements, a dipper presented 0.06 ml of water for 3 s. A houselight was located 19 cm from the floor and 12.2 cm from the chamber walls, on the wall opposite the wall with the response levers, and two lights could be turned on or off above each lever. All events in the experimental chamber were programmed and recorded using a computer compatible with IBM-PC interface DIG-700P1 and Windows MedPC software (SOF-735). The data were recorded using Schedule Manager software using Visual Basic that was developed especially for the present work.

Procedure

After lever pressing was shaped, the rats were gradually exposed to longer-duration FI schedules until a terminal value of 60 s was reached. The first response after 60 s since the last reinforcement was reinforced. This reinforced response turned off the light above the lever and activated the dipper, resulting in 3-s access to water. Thus, the first condition was a single FI schedule. In subsequent experimental conditions a multiple schedule was in effect in which a fixed duration component arranging extinction, where reinforcement was not available, was initiated after the access to water. In successive experimental conditions, these post-reinforcement extinction periods were 10, 20, 40, 80, and 160 s in duration. Each was associated with the darkened lights above either lever. Each extinction component ended with the light above the lever being turned on, which marked the onset of the FI 60-s schedule component. Sessions occurred three times per week, on Monday, Wednesday, and Friday for some rats and Tuesday, Thursday, and Saturday for the others. The rats were exposed to each experimental condition for a minimum of nine sessions. The stability criterion required that the medians of FI pausing for each group of three sessions showed no increasing or decreasing trend over the last nine sessions. For each rat, the median for that group of nine sessions was representative of that experimental condition. The data were recorded as IRIs, number of reinforcers delivered in the session, pauses in the FI schedules and the session duration. Pause during the FI was defined as the length of time between the onset of the discriminative stimulus (light) and the first response thereafter.

Results

Table 1 shows the number of sessions for each rat in each experimental condition. Figure 1 shows pauses in the FI schedule in each experimental condition. The data are medians for the last nine sessions in each experimental condition. The first vertical bar shows pauses when the FI schedule was programmed singly. For all rats pause durations were typical of single FI schedules, comprising from 60 to 80% of the interval. A FT 10-s schedule in the second experimental condition was sufficient to decrease FI pauses for all subjects. Pauses decreased systematically as the FT duration was lengthened in successive conditions, up to 160 s.

Table 1

Number of sessions for each rat in each experimental condition

Rats	FT Length					
	0 s (FI 60 s)	10 s	20 s	40 s	80 s	160 s
16	22	24	15	18	27	28
17	22	26	19	18	26	23
18	22	25	15	18	25	23
19	20	26	15	17	24	29
21	22	14	15	15	27	28

Figure 2 shows a sample, typical for all five rats, cumulative record of responding under the multiple FI 60-s extinction condition when the duration of the extinction component was 160 s. The short spaces between diagonal marks are periods between presen-

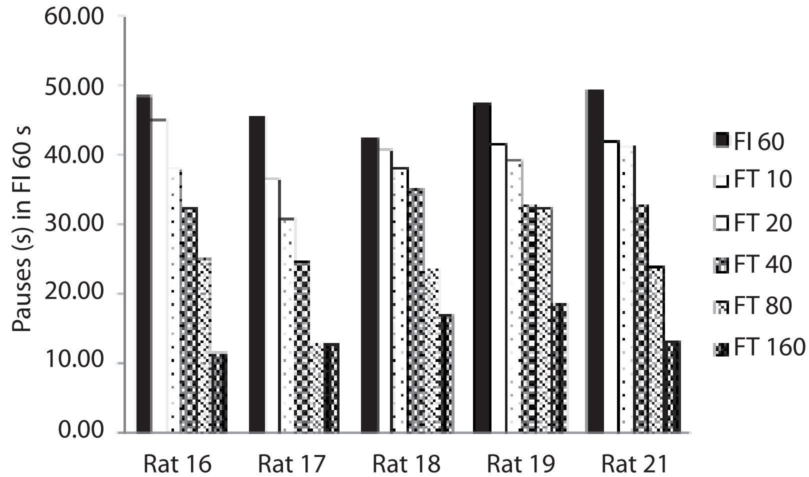

Figure 1. Pauses (s) in the initial part of FI schedules in the six experimental conditions. Data from five rats. The first (black) bars show pauses in single FI 60 s schedules; other bars show data from chain FT FI conditions. Data are medians of the last nine sessions in each condition.

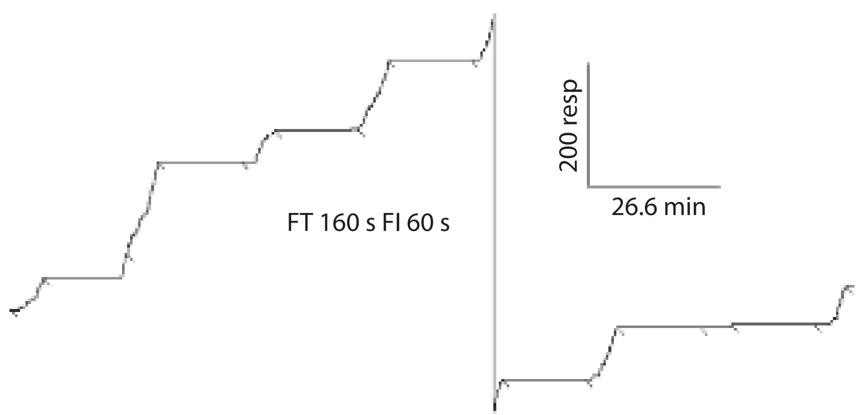

Figure 2. Cumulative record of responding (typical sample) during the multiple EXT FI 60 s schedule where the extinction component was in effect for 160 s. Diagonal deflections of the response pen show transitions from one component to the next of the chain. The record begins with responding on the FI 60 s schedule followed by pausing in the FT 160 s schedule ending when about 80% of the length had elapsed. In all other durations of the EXT period no responding was recorded, and in all other FI periods pauses were very short or nonexistent.

tation of the discriminative stimulus associated with the FI schedule and the presentation of primary reinforcement. Large spaces between those marks are records of responding during the FT schedule. The figure begins with responding during a FI period followed by a pause during FT, with responding resuming before the end of that FT period. All other FI periods show no or a short pause, and all FT periods show no responding.

Discussion

The present results show that a discriminative stimulus signaling time to the next access to primary reinforcement has a diminishing effect on responding when onset of that stimulus becomes disassociated with the last access to reinforcement. These results are consistent with data from multiple schedules (de Rose, 1986) and from chained schedules (de Souza & Todorov, 1976; Todorov & Teixeira-Sobrinho, 2009; Todorov et al., 2012). Pauses in single FI 60-s schedule were consistent with what is known about such temporal contingencies (e.g., Berry, Kangas, & Branch, 2012). The extended exposure to the same duration of the interval used in the procedure should result in longer or equal pause durations if the discriminative stimulus (light) is the only factor signaling time to the next primary reinforcer. The decrease in FI pause length as the extinction component duration was increased is consistent with the interpretation that both the discriminative stimulus signaling the next reinforcement and time since last primary reinforcer exert control over responding (e.g., de Rose, 1986).

de Rose (1986) observed the effect of different periods of extinction on pattern and rate of responding in three short FIs using a multiple schedule (which could as well be described as chained FT [extinction] FI schedules, with the end of the initial (extinction) link producing the discriminative stimulus for the FI schedule) and found that as duration of the extinction component increased, the temporal control exerted by FI contingencies diminished, especially for short FI durations. Both for the present data and for those from de Rose (1986), Todorov & Ferreira (1978), Todorov & Teixeira-Sobrinho (2009), and Todorov et al. (2012), the explanation may be in the functions exerted by primary reinforcers, as pointed out by Cowie, Davison, and Elliffe (2011). In typical single FI schedules a discriminative stimulus (S^D) is on for the duration of the FI interval and is turned off only during access to that reinforcer, so onset of the S^D signals extinction. Only prolonged presence of that stimulus turns it into a signal for reinforcement. In a multiple EXT FI schedules (de Rose, 1986), as in a chain FT FI, the extinction period is the absence of the S^D (or S-delta). Thus, the onset of S^D is a signal for reinforcement, especially for short FIs like the 60-s interval used in the present work, and the FI 18- and 30-s schedules used by de Rose.

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