ECCENTRIC STIMULI ON MULTIPLE FIXED-INTERVAL SCHEDULES¹

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The effects of presenting a different ("eccentric") stimulus for one interval during either or both components of a cyclic multiple fixed-interval fixed-interval schedule, with 12 short and four long intervals per cycle, were studied in three experiments. Eccentric stimuli in the short-interval component reliably produced a persistent, substantial elevation in key-peck rate. The effect appears to depend on schedule context and an initial "disinhibiting" effect of the eccentric stimulus.

The pattern and rate of operant responding in the presence of a stimulus are closely determined by the conditions of reinforcement associated with it. Consequently, two stimuli that signal the same conditions of reinforcement will usually maintain similar behavior. There are two kinds of exception to this simple rule, both of which refer to the effects of context.

(1) If the schedule associated with a given stimulus is notably "better" (or "worse") than that associated with another stimulus with which the first is intercalated, pigeons may peck faster (or slower) than if the stimulus occurred in isolation (behavioral contrast). Contrast effects have been observed with both aperiodic (variable-interval, VI: Reynolds, 1961) and periodic (fixed-interval, FI: Catania and Gill, 1964; Staddon, 1969) schedules. On aperiodic schedules, these effects are only weakly dependent on temporal order (sustained contrast: Nevin and Shettleworth, 1966), but on periodic schedules they are strongly time-dependent (transient or local contrast: Staddon, 1969).

(2) Some years ago, Pliskoff (1961) showed that a stimulus associated with the same conditions of reinforcement, in the same context, as another may nevertheless come to control a different response rate if it signals an impending

change in schedule. He used a baseline schedule in which VI 1-min and VI 10-min components, correlated with different stimuli (*mult* VI 1-min VI 10-min), alternated every 15 min. Separate "warning" stimuli, signalling the impending schedule change, were presented during the last 3 min of each 15-min exposure to a component of the multiple schedule. Response rate in the VI 1-min ("short-long": S-L) warning stimulus was lower, and rate in the VI 10-min (L-S) stimulus higher, than rate in the rest of the component.

The first of the present experiments explored the effects of "warning" (here termed *eccentric*²) stimuli on multiple fixed-interval fixed-interval schedules. Substantial effects were demonstrated under some conditions. However, later experiments showed that these effects do not depend on the warning property of these stimuli.

EXPERIMENT I: EFFECTS OF ECCENTRIC STIMULI SIGNALLING A CHANGE IN INTERREINFORCEMENT INTERVAL ("WARNING STIMULI")

METHOD

Subjects

Three adult, male White Carneaux pigeons, with experience on fixed-interval schedules,

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²Since the effect of these stimuli does not depend on their predictive significance, the terms "warning" or "preschedule-change" are inappropriate. "Eccentric" is used because the effects seem to depend both on the relative infrequency and the "novelty" of the stimuli.

were maintained at 80% of their free-feeding weights.

Apparatus

A standard single-key operant conditioning chamber for pigeons was used. The response key was transilluminated from behind by an in-line projector. Effective key pecks (minimum force 0.15N) were accompanied by an audible click from a feedback relay. Reinforcement consisted of 3.2-sec access to mixed grain, during which the keylight was extinguished and the feeder was illuminated. A dim house-light remained on throughout the session. The chamber was enclosed in a styrofoam sound-proofing box which, together with white noise and the noise of a ventilating fan, helped to mask extraneous sounds. All scheduling and recording equipment were in an adjoining room. Data were recorded on digital and printing counters and a cumulative recorder.

Procedure

The baseline schedule was cyclic multiple FI 1-min FI 3-min; each cycle was composed of twelve 1-min followed by four 3-min intervals. There were four cycles per session. The response key was green during the 1-min intervals and red during the 3-min intervals (reversed for Bird 41). In test conditions, eccentric ("warning") stimuli replaced the normal (background) stimulus for one short and one long fixed interval per cycle. The eccentric stimuli were: white key with three vertical dark bars ("short-long", S-L stimulus—this appeared throughout the last 1-min interval of each cycle), or white key with three horizontal dark bars (L-S stimulus—this appeared throughout the last 3-min interval of all cycles except the last in each session).³

This procedure is the only reasonable fixed-interval analogue to Pliskoff's *mult VI VI* "warning" procedure: if the "warning" stimulus had occurred for only part of the fixed interval, it would have had discriminative properties different from those of the other fixed-interval component stimulus, and these would have confounded any interpretation

based on the warning significance of the stimulus. The interval with the warning stimulus would effectively have become a two-stimulus "clock" schedule.

The five conditions in this experiment were as follows:

(1) Baseline training (53 sessions): all three birds were studied until stable on the baseline schedule without eccentric stimuli.

(2) Warning condition (26 sessions): both L-S and S-L eccentric (warning) stimuli were presented.

(3) Comparison condition (15 sessions): the warning and baseline procedures were run on alternate days.

(4) Baseline condition (14 sessions).

(5) Warning condition (seven sessions).

Pigeons were studied daily, and conditions were not changed until response-rate records showed at least five days of stable performance. In computing averages, the first twelve 1-min intervals in each session were not included.

RESULTS

Figure 1 compares performances on the baseline and first "warning" conditions (Conditions 1 and 2). The figure shows average, asymptotic response rate and postreinforcement pause in each of the 16 intervals (twelve 1-min and four 3-min) making up a cycle. The far right-hand panel shows the overall average rate, pause, and "running" rate (rate after the first peck of each interval). The location of the S-L and L-S warning stimuli is also shown on the average graph. (This method of averaging has been used before with mixed and multiple fixed-interval fixed-interval schedules, and fairly represents individual sessions, while reducing variability from interval to interval [e.g., Staddon, 1969; see Kello and Staddon, 1974, and Staddon, 1967, for cumulative records]). The essential findings are:

1. Response rate was much higher (and pauses much shorter) in the S-L stimulus than in the rest of the FI 1-min component (*i.e.*, in the "background" stimulus) or than in the last 1-min interval in the baseline condition. Most of the increase in response rate is due to the decrease in pause, but as the average shows, there was also some increase in running rate.

2. The L-S stimulus had little consistent effect.

3. As previously found with this baseline schedule (Staddon, 1969), response rate in the

³Due to a programming error, Bird 41 received an oblique (68° to the horizontal) rather than a horizontal bar stimulus during the last 3-min interval of the third cycle in each session. This seemed to make no difference to performance and these data are averaged with the rest.

Fig. 1. Response rate (upper panel) and pause (lower panel) in successive intervals of an average cycle on the *mult* FI 1-min (12 intervals) FI 3-min (four intervals) baseline condition (1) and the warning condition (2) for the three birds, and the average. Data are averaged across the last five days for each condition. The mean "running rate" (rate following the first response of an interval) is also shown for the overall average. Data for the last long interval in a session are not included, since there was no warning stimulus in this interval.

first short interval of each cycle was generally higher, and rate in the first long interval generally lower, than rate in the rest of the component (positive and negative local contrast).

4. Positive contrast effects were generally smaller in the warning condition than in the baseline condition, but negative contrast effects were little changed.

The rate-enhancing effect of the S-L stimulus was seen from the first day of the warning condition. For Bird 33, the effect was immediate, with pause decreasing and response rate increasing in the presence of the S-L stimulus each of the four times it occurred on the first day. For Bird 41, response rate dropped in the S-L stimulus on its first two occurrences in the first session, but in the last two cycles, rate increased above the background rate. Bird 34

showed no response-rate effect on the first day, though pause decreased. By the second session of the warning condition, every bird consistently pecked faster in the S-L stimulus.

On the first day of the first "warning" condition, postreinforcement pause in the L-S stimulus decreased greatly (although response rate changed little): mean pause in the fourth 3-min interval was 4.2 sec *versus* 36 sec in the third interval. However, this effect, unlike the comparable effect in the S-L stimulus, did not persist.

In Condition 3, the baseline and warning conditions were in force on alternate days, and in Conditions 4 and 5 they again occurred successively. The results of these replications of Conditions 1 and 2 were substantially the same as those of the originals, and are therefore not separately presented. The pause-

increasing, response-decreasing effect of the L-S stimulus seen for Bird 34 on the warning condition (Figure 1) gradually diminished, and was not seen after Condition 3.

DISCUSSION

In Pliskoff's (1961) *mult VI VI* study, both S-L and L-S "warning" stimuli had an effect on response rate. However, in the present *mult FI FI* experiment, only the short-long eccentric stimulus affected rate of pecking. One aim of the next experiment was to explore the effects of presenting the long-short stimulus in the absence of the short-long stimulus to see if any conditions could be found under which the L-S stimulus would have an effect.

In a later experiment, Pliskoff (1963) showed that response rate in a warning stimulus depended on whether the signalled schedule was associated with a higher or lower reinforcement rate than the schedule in the stimulus. His data establish an effect of schedule context on behavior maintained by an eccentric stimulus. However, Pliskoff did not explore the effect of presenting the eccentric stimulus in a position other than at the end of a component. Even on *mult VI VI* schedules, therefore, one cannot be sure that these effects depend on the "warning" property. On the *mult FI FI* schedule studied here, the rapid onset of the rate increase in the S-L stimulus argues against a true warning effect: one bird showed an effect the first time the eccentric stimulus was presented, and therefore could have had no opportunity to learn its "warning" significance. All of the others showed an effect within three or four exposures.

EXPERIMENT II: DETERMINANTS OF ECCENTRIC STIMULUS EFFECTS

Experiment I showed that an eccentric stimulus presented during one interval of the shorter component of a *mult FI 1-min FI 3-min* schedule substantially elevated rate of key pecking. The second experiment looked at the effects of stimulus type (novel *versus* familiar) and location (position in the sequence of 1-min intervals) on this rate elevation. The effect of schedule context was also studied.

Experiment I failed to find an effect of the L-S eccentric stimulus. In the second experiment, the L-S stimulus was presented without the S-L stimulus, and a new type of stimulus

was tried to see if some effect could be demonstrated. In a sensitive comparison condition, there was a small rate *increase* in the L-S stimulus; the large rate increase in the S-L stimulus appears to depend on "novelty" and schedule context, and not on the "warning" property.

METHOD

Subjects and Apparatus

These were the same as in Experiment I.

Procedure

Table 1 shows the sequence of experimental conditions and the number of sessions in each. The same *mult FI 1-min FI 3-min* baseline schedule was used as in Experiment I. The following factors were varied: (a) number of eccentric stimuli presented per cycle: both S-L and L-S, or only one of the two; (b) location of the FI 1-min eccentric stimulus, either in the twelfth or the sixth short interval of each cycle; (c) the eccentric stimuli used: vertical/horizontal ($90^\circ/180^\circ$) bars, as in Experiment I, green/red (*i.e.*, interchanging the component background color stimuli with the vertical/horizontal eccentric stimuli), or new eccentric stimuli, blue, "plaid" (a black, white, and gray grid-pattern obtained by activating several line-tilt stimuli at once in the in-line projector), and "oblique" (blue-on-white lines obtained by activating blue and diagonal black-and-white lines in the projector). (d) presence or absence of the FI 3-min component: in Condition 11, the FI 3-min component was omitted, and four consecutive cycles of twelve FI 1-min intervals were presented per session, with an eccentric stimulus in the sixth interval of each cycle. In addition, there were two recoveries of the baseline (Conditions 9 and 12) and two recoveries of the "warning" condition, one with the original eccentric stimuli (Condition 3), and the other with new stimuli (Condition 13).

In Conditions 1 to 5 and 8 to 11, Birds 33 and 34 had green in the 1-min fixed intervals and red in the 3-min interval (reversed for Bird 41), as in Experiment I. From Condition 12 on, all three birds had green in the short intervals and red in the long. Other details were as in Experiment I.

RESULTS

Figure 2 shows steady-state group average peck rate and postreinforcement pause data

Table 1

Conditions, Sessions, Location, and Type of Eccentric Stimuli in Experiment I

Condition	Sessions	Eccentric Stimulus		Comment
		FI 1-min (interval)	FI 3-min (interval)	
1	6	none	180° (4) ^a	L-S only
2	6	none	180° (4) ^{a, b}	
3	8	90° (12)	180° (4) ^a	warning
4	10	90° (6)	180° (4)	1-min ecc. + L-S
5	25	180° (6)	90° (4)	
6	18	green (6)	red (4)	ecc. and background interchanged
7	10	green (12)	red (4)	
8	18	90° (12)	none	S-L only
9	7	none	none	baseline
10	14	blue (6)	none	1-min ecc. only
11	21	blue (6) ^c	—	FI 1-min + ecc.
12	10	none	none	baseline
13	19	plaid (12)	oblique (4)	warning
14	12	none	oblique (4)	L-S only

^a68° for Bird 41 in third cycle.^bOnly in first and third cycles.^cBlue stimulus presented in intervals 6, 18, 30, 42 in each session.

plotted as in Figure 1. As in Experiment I, these averages are representative of the individuals. The data are arranged to allow appropriate comparisons, as follows:

The second panel of Figure 2 shows the results of two conditions (4 and 5) in which the 1-min eccentric stimulus was presented in the sixth (rather than the last) 1-min interval. Both stimuli produced the same substantial response-rate elevation (and pause decrease) seen in Experiment I with an eccentric stimulus in the last 1-min interval.

The third panel compares the rate profiles during the 1-min portion of the *mult* FI 1-min FI 3-min schedule with performance on simple FI 1-min. In the first case, a novel (blue) eccentric stimulus occurred during the sixth 1-min interval; on the simple FI 1-min schedule, the blue stimulus occurred during every twelfth interval throughout the session, beginning with the sixth (so there were the same number of eccentric stimulus presentations per session for both). Response-rate elevation in the eccentric stimulus (relative to the background) occurred only in the multiple condition.

The last panel compares the two conditions in which the eccentric stimuli were interchanged with their corresponding background stimuli (1-min eccentric with 1-min background, *etc.*). The swap occurred first in Condition 6, with the 1-min eccentric stimulus

in the sixth interval. The “new” 1-min eccentric stimulus produced a small decrease in pause and no rate elevation, and the elevation in the background (previously eccentric) stimulus did not persist. Shifting the eccentric stimulus to the “warning” position (twelfth 1-min interval) in Condition 7 had no effect. Overall, the rate profiles in these two conditions resembled the baseline pattern, with no consistent differential effect of the eccentric stimuli.

The first panel of Figure 2 shows performances with only an L-S (fourth 3-min interval) eccentric stimulus. The most sensitive comparison is in Condition 2, when the L-S stimulus was presented during only the first and third cycles, so that the second and fourth cycles constitute a “no-warning” baseline condition. Performance in the last 3-min interval under these conditions is shown. The L-S stimulus decreased pause and increased peck rate, compared with the baseline condition, but the effects were variable and not large. Comparison of the overall rate profiles for Conditions 1 and 14 (in which only the L-S stimulus was presented) with the S-L and L-S “warning” condition in Figure 1 suggests that the presence or absence of the S-L stimulus had no effect on responding in the presence of the L-S stimulus. Similarly, performance in the S-L stimulus in Condition 8, in which the S-L stimulus was presented without the L-S stim-

Fig. 2. Response rate (upper panel) and postreinforcement pause (lower panel) in each interval of an average cycle for the conditions of Experiment II. Each curve is the average of the three pigeons. First panel: performance when the L-S stimulus was presented in the absence of the S-L stimulus. Second panel: two conditions in which the short-interval eccentric stimulus was presented in the sixth rather than the last short interval of each cycle. Third panel: effects of a new eccentric stimulus in the sixth short interval, with (Condition 10) and without (Condition 11) a long-interval component. Last panel: effects of interchanging the background and eccentric stimuli, with the eccentric stimulus either in the sixth (Condition 6) or the last (Condition 7) short interval. Arrows show location of eccentric stimuli (see Table 1). Other details are as in Figure 1.

ulus, was similar to performance when both were presented. Responding in each stimulus was independent of the occurrence of the other.

Performance on the baseline and warning replications differed little from that in Experiment I. As in Experiment I, the effects of the short-interval eccentric stimulus occurred in the first session of each condition, with Bird 41 being somewhat slower than the others to show the effects.

DISCUSSION

The effects of eccentric stimuli do not depend on their "warning" significance. This is shown by the immediacy of the effects (seen in both experiments), by their persistence when the S-L stimulus was moved from the twelfth to the sixth 1-min interval, by their occurrence when the hitherto ineffective L-S (3-min) stimulus was presented in the sixth 1-min interval (Condition 5), and by their occurrence when a novel stimulus was presented for the first time in the sixth 1-min interval (Condition 10).

The effects appear to depend on schedule context, since the differential effect of the short-interval stimulus was much reduced by the shift from *mult* FI 1-min FI 3-min to simple FI 1-min (Conditions 10 and 11)—although this conclusion is weakened by the overall rate increase in the FI 1-min condition. These data suggest that the rate elevation in an eccentric stimulus is directly related to the relative rate of reinforcement in the background stimulus, and may therefore be related to behavioral contrast. This would account both for the reduction in the effect following the shift from *mult* FI 1-min FI 3-min to simple FI 1-min (only in the former case is FI 1-min the "relatively better" component), and for the much smaller rate increase produced by the 3-min eccentric stimulus (FI 3-min was always the "relatively worse" component).

The short-interval eccentric stimulus effect was abolished by interchanging eccentric and background stimuli in Condition 6. Since the

old background stimulus maintained a relatively low rate, the swap produced no immediate rate increase. Thus, the effect of reinforcement context on the rate elevation produced by an eccentric stimulus may be a sustaining rather than an inducing one: if there is no immediate rate-increasing ("disinhibiting") effect when the eccentric stimulus is first introduced, there will be no maintained effect either. On the other hand, an immediate effect of the eccentric stimulus is not sufficient by itself, as shown by the transience of the large first-day pause decrease produced by the 3-min eccentric stimulus in Experiment I.

EXPERIMENT III: EFFECTS OF RELATIVE AND ABSOLUTE INTERVAL DURATION

Two results of Experiment II point to an effect of reinforcement context on performance in an eccentric stimulus: the almost complete abolition of the rate increase in the 1-min stimulus following the shift from *mult* FI 1-min FI 3-min to simple FI 1-min, and the much smaller rate elevation in the long-interval (FI 3-min) eccentric stimulus. The third experiment explored this context-dependency further, using a cyclic multiple schedule similar to the previous schedule but with intervals only one third as long.

METHOD

Subjects and Apparatus

There were the same as in the first two experiments.

Procedure

The baseline schedule was cyclic *mult* FI 20-sec FI 60-sec; each cycle was composed of twelve 20-sec followed by four 60-sec intervals. There were four cycles per session. The key was green during the 20-sec intervals and red during the 60-sec intervals. There were three conditions: 1. L-S, oblique (23 sessions): the birds received the oblique eccentric stimulus (see Experiment 2) during the last 60-sec interval. 2. S-L, plaid (23 sessions): the birds received the plaid eccentric stimulus (see Experiment 2) during the last 20-sec interval. 3. Baseline (nine sessions): the birds received no eccentric stimulus. Other details are as in the first two experiments.

RESULTS

The results are summarized in the average

cycles shown in Figure 3. The 20-sec (S-L) eccentric stimulus elevated response rate but had little effect on postreinforcement pause. Hence, the main effect was on "running" rate. The 60-sec (L-S) stimulus had little effect.

Positive contrast effects increased across conditions, owing to a progressive decrease in peck rate in intervals after the first in each cycle. Negative contrast effects were negligible. Average peck rates in the 20-sec background stimulus were higher than rates in the 60-sec background stimulus.

DISCUSSION

The results of this experiment confirm conclusions drawn from the first two experiments: only the short-interval eccentric stimulus elevated response rate, even though the long-

Fig. 3. An average cycle on the *mult* FI 20-sec (12 intervals), FI 60-sec (four intervals) schedule with a L-S stimulus (Condition 1), with a S-L stimulus (Condition 2), and with no eccentric stimuli (baseline, Condition 3). Other details are as in Figures 1 and 2.

interval stimulus was the same duration (1 min) as the effective short-interval stimulus in the previous experiments. Unfortunately, no attempt was made to compare *mult* FI 20-sec FI 60-sec with simple FI 20-sec, so it is not known whether there is an interaction between absolute and relative reinforcement rate.

Average response rate (excluding local contrast effects) in the short- and long-interval background stimuli differed little in Experiments I and II, with 1-min and 3-min intervals, but differed substantially here, with 20- and 60-sec intervals. This difference confirms previous comparisons between short and long absolute interval values (Staddon, 1969). The small positive contrast, and negligible negative contrast, here by comparison with the data of Staddon (1969) may reflect the more prolonged training in the present experiment.

GENERAL DISCUSSION

The novel result here is the response-elevating effect of an "eccentric" stimulus presented for a single interval during the short-interval component of a *mult* FI FI schedule. This effect did not depend on the predictive significance of the stimulus location, as indicated by the immediate onset of the effect, and by its appearance when a new eccentric stimulus was presented in the middle (rather than at the end, as a "warning" stimulus) of each series of short intervals. The effect did depend on context, *i.e.*, on *relative* rather than absolute reinforcement rate in the "background" stimulus, as shown by demonstration of the effect in the FI 1-min component of the *mult* FI 1-min FI 3-min schedule, and failure to show it in the FI 60-sec component of the *mult* FI 20-sec FI 60-sec schedule in Experiment II. The effect appears to depend on the "disinhibiting" property of the eccentric stimulus: it was successfully demonstrated with various "novel" stimuli, but failed to appear when eccentric and background stimuli were interchanged. Under these conditions, the new eccentric stimulus is obviously not novel and would not be expected to disinhibit FI responding.

The high rate in the short-interval eccentric stimulus was not maintained when it became the new background stimulus (Conditions 6 and 7, Experiment II). This suggests that the rate-enhancing effect may depend on the rela-

tive frequency of occurrence of the stimulus: the more frequently it occurs, the less persistent the anomalous high rate in its presence. This factor may also contribute to the failure to find much response elevation in the long-interval eccentric stimuli, since they occurred in one of four intervals, whereas the short-interval stimuli occurred in only one of 12.

The rate-enhancing effects here appeared to persist indefinitely. However, the birds were exposed to the short-interval eccentric stimulus only four times per session, whereas they experienced the short-interval background stimulus 44 times each session. Whether the greater persistence of the effect under the former conditions is solely a function of infrequency of presentation, or whether it represents a truly permanent rate elevation, cannot be decided with the present data. It is possible, however, that the short-interval effect represents a more or less permanent "fixing" of a normally transient disinhibiting effect, under conditions of high relative frequency of reinforcement. If this is a general effect, it should be of interest to students of stimulus control.

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