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RATE-CHANGE EFFECTS WITH EQUAL POTENTIAL REINFORCEMENTS DURING THE "WARNING" STIMULUS[1]

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Two pre-schedule-change stimuli were superimposed on the same VI baseline and were thereby equated with respect to reinforcement potential. One such stimulus preceded a transition to an extinction schedule or a VI schedule of lower reinforcement frequency while the other preceded a transition to a VI schedule of higher reinforcement frequency. It was found that response rate during the warning stimulus was greater preceding the transition to the lower reinforcement frequency than it was preceding the transition to the higher reinforcement frequency. That difference was often evidenced by an absolute increase and decrease in rate, in conformity with previous findings on the topic. The present experiment extends previous findings in several ways, including the presentation of quantitative estimates of the effects.

Previous work (Pliskoff, 1961) demonstrated some distinctive changes in response rate during a pre-schedule-change stimulus ("warning" stimulus) on a multiple variable-interval, variable-interval schedule of reinforcement where the two VIs were quite different with respect to reinforcement frequency. It was concluded that response rate (key pecking by pigeons) decreased in a short, discriminated interval before a shift to a higher frequency-of-reinforcement VI schedule, and increased in a similar interval before a shift to a lower frequency-of-reinforcement VI schedule.

When the rate-change effects in question are studied within the context of a simple Mult VI VI, the two VI schedules are alternated, with each one in effect for a specified period of time. During the short period of time immediately preceding the transition from one schedule to the other, the warning stimulus is turned on, and it remains on until the schedule transition occurs. In the simplest case, the reinforcement schedule during the warning stimulus is the same as that in effect during the baseline VI performance upon which the warning stimulus is superimposed.

Since two VI schedules are employed, each with its own superimposed warning stimulus, there must be different reinforcement tapes in effect during each of the two warning stimuli. If the two warning stimuli are of equal duration, then it follows that they must differ with respect to the average number of reinforcements the animal can obtain (reinforcement potential) in their presence. The data previously reported (Pliskoff, 1961) showed a rate decrease during the warning stimulus on VI_{10}—the warning stimulus characterized by the lower reinforcement potential (0.3) and a history of succession by VI_1. Further, the rate increase was obtained during the warning stimulus on VI_1, with the higher reinforcement potential (3.0) and a history of succession by VI_{10}.

The purpose of the present experiment was to determine whether or not warning-stimulus rate changes such as those mentioned above could be obtained if the same reinforcement potential, rather than different ones, characterized the two warning stimuli.

METHOD

Subjects and Apparatus

Four experimentally naive, male White Carneaux pigeons (*S*s) were reduced to 80% of their stable free-feeding weights for magazine training and CRF. During the experiment the birds were run between 75 and 82%

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of free-feeding weight with the value constant for each animal.

The apparatus consisted of an animal chamber with manipulandum and feeder designed for a pigeon, in addition to the usual programming and recording equipment.

Procedure

Following magazine training and CRF on white, red, and green keys, *S*s were placed on a complex multiple schedule, diagrammed in Fig. 1 and described below. A white response key was presented for 10 min. At the termination of the 10 min, the key turned either red or green for another 10 min. Following red or green, the white key was reintroduced. Thus, a daily session (61 reinforcements) consisted of a sequence of white, red or green, white, red or green, white, *etc.* Furthermore, the sequence was arranged so that (1) red followed white equally often as did green, and (2) the order of red and green keys after white was nonsystematic.

The transition from the red or green key to the white key was not preceded by a warning stimulus. The transition from white to green was preceded by a blinking (about 3 flashes per sec) house light on the upper right side of the front wall; the transition from white to red was preceded by a steady house light on the upper left side of the front wall. The warning stimulus terminated, independently of *S*s' behavior, coincidentally with the transition to the red or green key, and the house lights were never used in any capacity other than as warning stimuli. Reinforcements set up but not collected during the warning stimuli were lost.

Four experimental conditions can be identified by reference to the VI schedule of reinforcement in each of the three key colors and the duration of the warning stimuli:

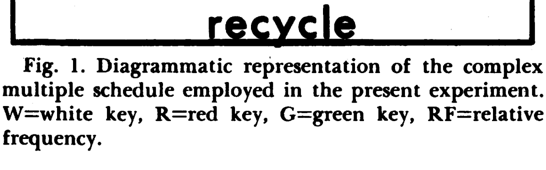

Fig. 1. Diagrammatic representation of the complex multiple schedule employed in the present experiment. W=white key, R=red key, G=green key, RF=relative frequency.

1. VI_2 in white, VI_2 in green, VI_2 in red; both warning stimuli, 1 min in duration.
2. VI_2 in white, $VI_{0.5}$ in green, VI_{15} in red; both warning stimuli, - min in duration.
3. $VI_{3.5}$ in white, $VI_{0.5}$ in green, Extinction in red; both warning stimuli, 2 min in duration.
4. $VI_{3.5}$ in white, $VI_{3.5}$ in green, $VI_{3.5}$ in red; both warning stimuli, 2 min in duration.

RESULTS

Complete rate data for the four birds are presented in Fig. 2. Each quadrant of the figure is divided into an upper and lower portion; the upper portion presents absolute response rate (responses per sec) in each of the three key colors. The rate plots are identified by the three-item key at the top of the quadrant for Bird 17. The entries for red and green are based on total exposures to those key colors; the rates for white are based on the total exposures less (1) the period of the warning stimuli and (2) a period of time equal to and immediately preceding the warning stimuli (control period).

The lower part of each quadrant presents data derived from rates obtained during the warning stimuli and the immediately preceding control period. Each entry is a ratio (W/C) of warning stimulus to control rates.

As indicated in the key for the lower part of the quadrant for Bird 17, the open circles are the daily ratios preceding the transitions to the red key, and the filled, connected circles are the daily ratios preceding the transitions to the green key. Note that the ratios are computed from rates obtained on the white response key only, the two plots differing in terms of the prevailing warning stimulus and its correlated consequent transition. Clearly, a W/C ratio greater than unity indicates a tendency for the warning stimulus response rate to exceed the control rate, while a W/C ratio less than unity indicates the opposite tendency.

The four experimental conditions reported herein are marked off by vertical lines and numbered in the quadrant for Bird 32 only, although the analagous divisions may be recognized in the plots for the other three birds also.

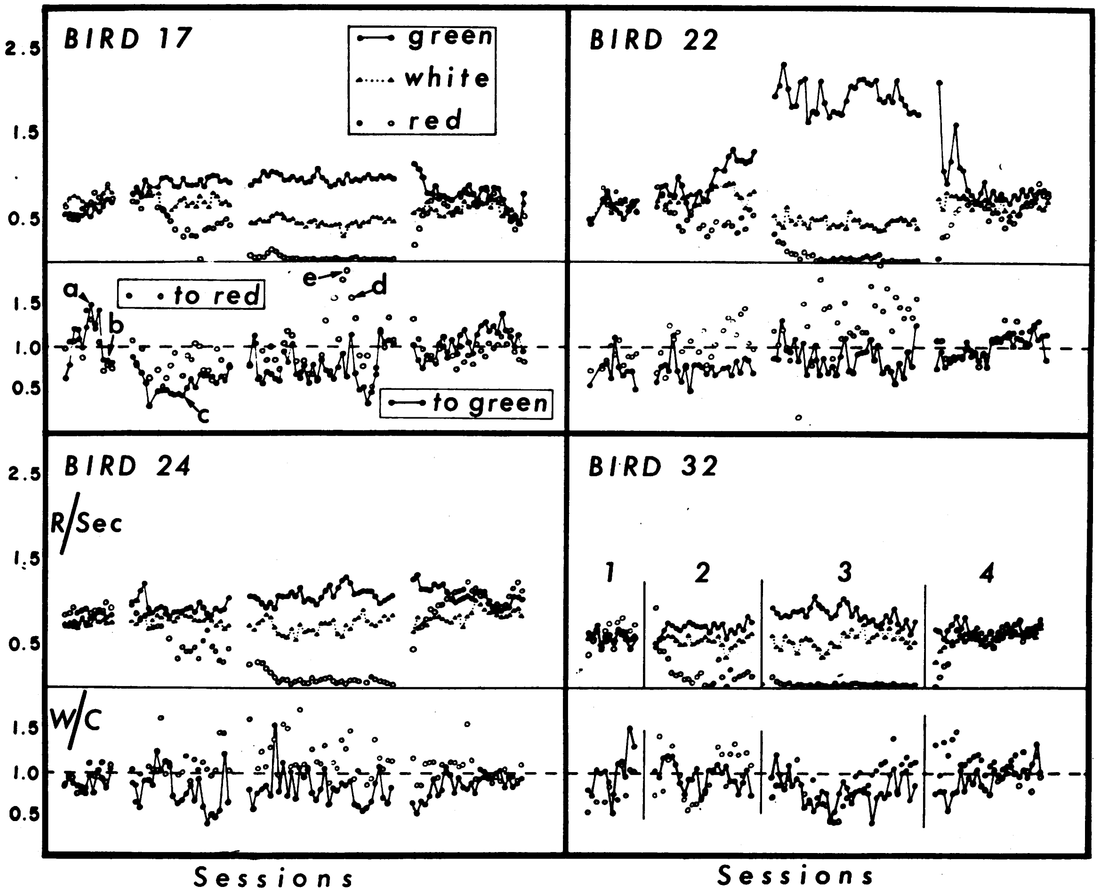

Fig. 2. Each of the four quadrants contains complete data for one of the birds. The quadrant for each bird is divided into two parts: the upper shows absolute response rate on the three key colors. The lower part shows the ratio between warning stimulus and control rate, the latter taken from a period of time equal to and immediately preceding the warning stimulus. The four experimental conditions studied are marked off and labeled for Bird 32 only, but apply to all four. The ordinates are labeled on the inside of the quadrant for Bird 24 only, but apply to all four. The four experimental conditions were:

1. VI$_2$ in white, VI$_2$ in green, VI$_2$ in red; both warning stimuli, 1 min in duration.
2. VI$_2$ in white, VI$_{0.5}$ in green, VI$_{15}$ in red; both warning stimuli, 1 min in duration.
3. VI$_{3.5}$ in white, VI$_{0.5}$ in green, Extinction in red; both warning stimuli, 2 min in duration.
4. VI$_{3.5}$ in white, VI$_{3.5}$ in green, VI$_{3.5}$ in red; both warning stimuli, 2 min in duration.

The absolute response rates for all four birds during Condition 1 are between 0.5 and 1.0 response per sec and are not differentiated by key colors. It was during this experimental condition that the reinforcement schedule was VI$_2$ in the three colors. The W/C ratios during Condition 1 are variable from session to session. It should be noted that the response rates upon which they are based, in contrast to those plotted above, are calculated from relatively brief time samples—in the order of several minutes per calculation.

In spite of the variability of the W/C ratios in Condition 1, there is little or no tendency for the two W/C ratios for each bird to establish a differential pattern over daily sessions. Particularly interesting are the data for Bird 17. The ratios shown begin below unity, drift upward to about 1.5 and then drop to about 0.75. Only in the case of Bird 24 are the W/C ratios for Condition 1 relatively stable from day to day.

Condition 2, where the three key colors were correlated with different reinforcement frequencies (VI$_2$ in white, VI$_{0.5}$ in green, VI$_{15}$ in red), produced a divergence of the absolute response rates after several sessions. The rate on the white key demonstrated the least overall change (none detectable for Birds 17, 24, and 32), and it was for this key color that the reinforcement schedule remained constant at VI_2 relative to Condition 1. Perhaps the most significant change in response rate for any of the three keys was in red where the reinforcement schedule was now VI_{15}.

Consideration of the W/C ratios for Condition 2 shows a tendency for them to separate in two different ways relative to a W/C ratio of unity, which represents no rate-change during the warning stimulus with respect to the immediately preceding control period: (a) both W/C ratios are below unity with the one preceding the transition from VI_2 to VI_{15} being above the one preceding the transition from VI_2 to $VI_{0.5}$; (b) the W/C ratio for the VI_2 to VI_{15} transition is above unity and the W/C ratio for the VI_2 to $VI_{0.5}$ transition is below unity. Bird 17 exemplifies the first case; its warning stimulus performance displays a consistent tendency toward reduced rate, with the reduction being more marked preceding a transition to a higher frequency-of-reinforcement VI schedule. In contrast, Birds 22 and 24 displayed the second case—a tendency to suppress preceding the transition to the $VI_{0.5}$ and an overall tendency (with exceptions) to increase response rate when the warning stimulus is appropriate to the transition to VI_{15}. Note, however, that in the case of Bird 22, the separation between the two types of W/C ratios is produced primarily by an increase in the ratio for the transition to VI_{15}. In the case of Bird 24, the effect appears as an increase in one ratio and a decrease in the other. The response of Bird 32 to Condition 2 is not clear; separation in the W/C ratios is not apparent until, perhaps, 10 sessions from the end of Condition 2.

A comparison of the upper and lower frame for each bird yields an observation of some interest. Note that for each bird with the exception of Bird 32, the separation in W/C ratios begins roughly at about the same time as does the separation among absolute rates in the three key colors.

At this point in the experiment, several procedures were introduced in order to exaggerate the rate-change effects described above. One of them did so and is reported as Condition 3. Note, therefore, that there were several weeks of experimental sessions intervening between Conditions 2 and 3, and the curves drawn in Fig. 2 are not continuous in that respect.

Condition 3 represents the effects obtained when the several VIs were made more extreme with respect to each other. The VI on the green key was kept at 0.5 min; the VI on the white key was changed from 2 min to 3.5 min, and the schedule on the red key was changed from VI_{15} to Extinction.

The changes in absolute response rates produced by the schedule variations agree with what might be expected. Perhaps the most noticeable one is the decrease in rate on the red key. The marked rate increase in green shown by Bird 22 most likely was not a result of schedule changes inasmuch as *S* had been showing a drift upward on that key for weeks with the schedule parameters constant.

Of particular interest are the changes in the W/C ratios produced by the change in reinforcement frequencies on the white and red keys. Examination of the lower panels of Fig. 2 for each bird shows an increase in the tendency for the W/C ratios to separate—Bird 22 in particular showed increased W/C ratios for the warning stimulus preceding the extinction key. Although on several sessions its W/C ratio for the warning stimulus preceding the transition to $VI_{0.5}$ (solid, connected circles in figure) was greater than unity, the overall tendency was clearly to reduce response rate during that stimulus. The same conclusions hold for Bird 24. Bird 17 is interesting in that it developed for the first time a clear-cut tendency to increase response rate in the warning stimulus preceding the red key—this developing tendency was accompanied by a continued tendency to suppress in the other warning stimulus. Again, the performance of Bird 32 is not clear.

Condition 4 was a control for the effects described above—the schedule of reinforcement on all three keys was set at a VI of 3.5 min. Without exception, absolute response rates (upper panels of Fig. 2) converged. The limit of the convergence was a value approximately, but slightly higher than, the $VI_{3.5}$ rate on the white key during Condition 3.

Note the effect of Condition 4 on the W/C ratios—both ratios for each bird converge toward a common value in the vicinity of unity. The convergence indicates a loss of the tendency to differentially alter response rate during the warning stimuli.

Both Conditions 1 and 4 represent control sequences in that the variable interval schedule is the same in all three key colors. The Condition 4 W/C ratios are preferable to those of Condition 1 for purposes of comparison with Conditions 2 and 3 in that they display increased stability relative to those of Condition 1. The increased stability is most likely the result of (a) the warning stimulus and control periods for Condition 4 are double those of Condition 1, and, (b) the performances in Condition 4 were relatively smooth after several months of experimentation.

Figure 3 shows cumulative records of characteristic warning stimulus performance. The pips on the records mark reinforcements; the presence of a warning stimulus in the experimental box corresponds with the extensive depressions of the pen. Reinforcements are not marked during the warning stimuli. All of the records shown in Fig. 3 were taken from the data for Bird 17—that *S* ran the gamut of possible effects, and, in that respect, was representative. Note also that each frame, *a* through *e*, represents all of the warning stimuli and transitions for the entire session, and that the session in question is marked in Fig. 2 with the corresponding letter.

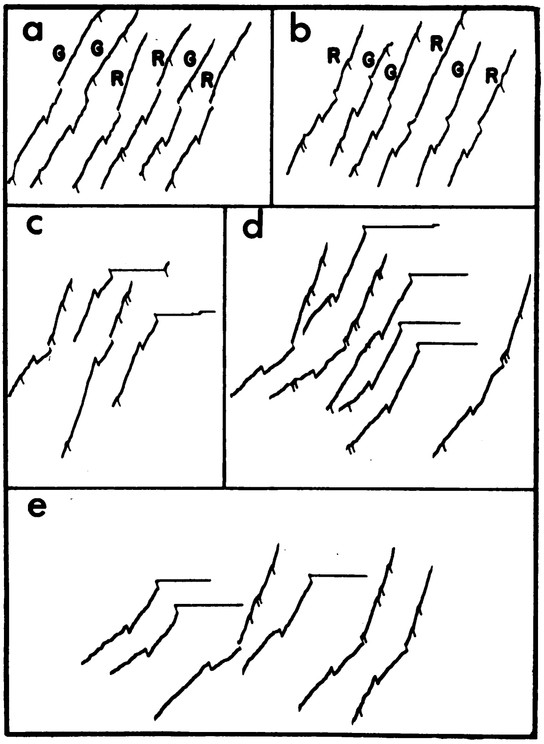

Fig. 3. Representative cumulative records displaying several kinds of warning stimulus performance. All records are for Bird 17, and each frame shows all of the warning stimuli from a complete session. Each session is identified by the corresponding letter in Fig. 2.

Frames *a* and *b* were taken from Condition 1 where all of the VIs were 2 min. In frames *a* and *b*, the key color following the warning stimuli and transitions are marked green or red. Frame *a* was taken from a session in which Bird 17 displayed a tendency to increase rate, and it would appear that that tendency was an effect of the warning stimulus itself. There is no great differential effect as a consequence of the impending transition to the red or green key. That a rate increase is not typically associated with the presence of a warning stimulus is shown by Frame *b*, where, with the same reinforcement contingencies in effect, the warning stimuli tend largely to produce a reduction in rate.

Frames *c*, *d*, and *e* are taken from sessions in which the three key colors were associated with reinforcement schedules differing in reinforcement frequency. It may be seen from Fig. 2 that in the session marked *c*, Bird 17 tended to suppress response rate in the presence of both warning stimuli, although to a greater extent in the presence of the warning stimulus preceding the transition to the higher reinforcement frequency VI. Frame *c* of Fig. 3 shows the warning stimulus performances on that day. (The key color or schedule produced by the transition following each warning stimulus is not marked inasmuch as the performance record indicates clearly which of the two reinforcement frequencies was in effect following each transition.) Note that on the two occasions in which the warning stimulus signals a transition to the $VI_{0.5}$ the onset of the warning stimulus produced a clean break in rate in the direction of decreased output. In contrast, the remaining two records, where the warning stimulus preceded a transition to VI_{15}, indicate a relatively sustained rate for about 15 sec after the onset of the warning stimulus.

Frame *d* is taken from a session in which, with different reinforcement frequencies in the several key colors, a tendency to increase response rate in both warning stimuli (now 120 sec in duration) was apparent, although the tendency to increase rate was markedly greater during the warning stimulus preceding the red key (now Extinction). In contrast, Frame *e* shows a session in which there was a marked tendency to increase rate during the warning stimulus preceding the extinction key and a clear tendency to reduce response rate during the warning stimulus preceding $VI_{0.5}$.

DISCUSSION

The procedure utilized in the present experiment was designed so that the same VI reinforcement tape would run during the two warning stimuli, thus permitting them to differ only in terms of their consequent transitions. The results have demonstrated that the warning stimulus rate-change effects are not primarily determined by differential reinforcement potentials during the warning stimuli.

Examination of Fig. 2 indicates that no simple characterization of the data would serve adequately. Two conclusions are preferred. The first is unrestricted by the "no-change" condition (*i.e.*, a W/C ratio of unity), and points simply to the fact that the W/C ratio is higher for the transition to the VI schedule of lower reinforcement frequency (open circle) than is the same-day W/C ratio for the transition to the VI schedule of higher reinforcement frequency (filled, connected circle). The performances of Birds 17, 22, and 24 support that conclusion rather strongly. On only rare occasions during Conditions 2 and 3 is a reversal of that conclusion in evidence. Since the control rates for the two types of transition were about equal, that observation can be stated in terms of absolute response rates during the warning stimuli: response rate during the warning stimulus is higher preceding the VI schedule of lower reinforcement frequency than it is preceding the VI schedule of higher reinforcement frequency.

A conclusion made more restrictive by its dependence on the "no-change" W/C ratio of unity[2] states that the W/C ratio for the transition to the lower reinforcement frequency VI is above unity while the W/C ratio for the transition to the higher reinforcement frequency VI is below unity. In terms of absolute response rates during the warning stimuli, this conclusion specifies the occurrence of rate increases ("running") and decreases ("suppression") relative to a control rate. Previous work (Pliskoff, 1961) was characterized in this fashion, as work in this general research area often is (*e.g.*, Ferster, 1958, 1960).

A consideration of Fig. 2 indicates that the restrictive conclusion was weakly supported by the present data. There were numerous exceptions to the rate-increase-in-one-warning-stimulus, rate-decrease-in-the-other arrangement of data points. Note, however, that those exceptions to the restrictive conclusion are not exceptions to the first, less restrictive conclusion. A prime case in point is the performance of Bird 17 during Condition 2.

Several aspects of the W/C ratio data of Fig. 2 support the impression that Condition 3, with the more extreme set of reinforcement frequencies, provided stronger support for the more restrictive conclusion than did Condition 2. Bird 17, for example, began showing for the first time W/C ratios appropriately greater than unity. Bird 22 showed no open-circle W/C ratios less than unity during the second half of Condition 3.

It is suggested tentatively that the relationship between the two W/C ratios expressed by the first conclusion is the fundamental one in the sense that it appears with less extreme transitions in reinforcement density. As those transitions become more extreme, clear "running" and "suppression" effects appear.

Traditional experimental designs in this research area (*e.g.*, Ferster, 1958) are truncated in that they involve a study of the warning stimulus performance preceding the transition only from a higher to lower reinforcement density. When the lower reinforcement density is zero, as it is when extinction or a black out follows the pre-schedule-change stimulus, a rate increase during the warning stimulus is typically found. Condition 3 data, suggesting the second, restrictive conclusion, are in complete agreement with those findings.

REFERENCES

Ferster, C. B. Control of behavior in chimpanzees and pigeons by time out from positive reinforcement. *Psychol. Monogr.*, 1958, 72, No. 8 (Whole No. 461).

Ferster, C. B. Suppression of a performance under differential reinforcement of low rates by a pre-time-out stimulus. *J. exp. Anal. Behav.*, 1960, 3, 143-153.

Pliskoff, S. S. Rate-change effects during a pre-schedule-change stimulus. *J. exp. Anal. Behav.*, 1961, 4, 383-386.

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[2] It is also more restrictive in the sense that any pair of same-day counterpart W/C ratios that support the more restrictive conclusion also support the less restrictive. The converse implication, however, is not true.