AN ANALYSIS OF CONTRAST EFFECTS IN MULTIPLE SCHEDULES¹

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Some phenomena of behavioral contrast in multiple schedules are reviewed, and three accounts of contrast are considered. Rate changes within a constant schedule component (transient contrasts) are distinguished from rate changes across successive schedule cycles (sustained contrasts). Pigeons were exposed to a three-component multiple schedule, in which a stimulus correlated with a constant variable interval schedule of reinforcement was preceded by a stimulus correlated with more frequent variable interval reinforcement, or by an extinction stimulus. If the preceding stimulus was correlated with more frequent reinforcement, the response rate in the constant component was low and increased with time. If the preceding stimulus was correlated with extinction, the rate in the constant component was high and decreased with time. Similar transient contrasts were observed in a two-component multiple schedule with different variable interval schedules in the two components. The transient contrast effects in the three-component schedule were shown to depend on differential reinforcement frequency rather than differential response rate in the preceding component. Such transient contrasts were not sufficient to account for sustained contrast effects observed in these experiments. The relation of these findings to the concepts of excitation and inhibition is discussed.

In a typical multiple schedule, two stimuli correlated with independent schedules of reinforcement are successively presented to the subject. If the schedule in one stimulus is varied, behavior in the alternated stimulus may change even though its associated schedule remains constant. Such an interaction is called contrast if response rates change in opposite directions. Contrast seems to be an almost invariable effect of successive discrimination training involving extinction in one stimulus. Thus, an analysis of contrast may contribute to an understanding of the processes involved in stimulus control of operant behavior.

Variables producing contrast effects in multiple schedules are reviewed briefly. Only experiments using variable interval schedules of reinforcement in the constant component are considered, because on such schedules, the frequency of reinforcement remains constant

over wide ranges of response rates. Therefore, contrast cannot be attributed to changes in reinforcement frequency within the constant component. Except as noted, pigeons were used as subjects, with rate of key-pecking as the dependent variable.

Contrast is most reliably produced by introducing a stimulus correlated with extinction (Terrace, 1963a), or by changing the schedule in one component from variable interval (VI) to extinction (*ext*) or time out (Reynolds, 1961a, b; Friedman and Guttman, 1965). It may also be produced by systematically manipulating the value of a fixed ratio (FR) (Reynolds, 1961c) or a variable interval (Reynolds, 1963) schedule in the varied component. However, if an extinction stimulus is introduced using special training procedures so that few "errors" occur, there is no contrast effect (Terrace, 1963a). If the schedule in the varied component is changed from VI to DRO (differential reinforcement of other behavior) so that reinforcement occurs fairly frequently despite the absence of responding, no contrast effect is observed (Reynolds, 1961a).

Reynolds (1961c, 1963) has suggested that contrast effects depend on changes in the relative frequency of reinforcement in the constant component which result from changes

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in reinforcement frequency in the varied component. In an experiment with VI reinforcement available concurrently with a *mult* VI *ext* schedule, Catania (1961) found that the magnitude of the contrast effect on the multiple key was an increasing function of the per cent decrease in reinforcement frequency determined by concurrent reinforcement during the *ext* component. Reynolds (1961*d*) found a similar relation in contrast effects observed in discrimination gradients: changing relative reinforcement frequency in the constant component from 0.10 to 0.50 produced a larger contrast effect than changing from 0.10 to 0.125. Such evidence of functional control of the magnitude of contrast by changes in relative reinforcement strongly supports this interpretation. However, not all contrast effects depend on changes in relative reinforcement. Terrace (1963*a, b*) demonstrated the dependence of contrast on occurrence of unreinforced responding in the extinction stimulus, with no changes in reinforcement frequency. Brethower and Reynolds (1962) produced contrast by introducing punishment in the varied component, resulting in suppression of responding without appreciable changes in reinforcement frequency.

Terrace (1963*a, b*, 1966) has argued that stimuli correlated with reduction of rate through extinction, schedule change, or punishment, as well as immediate elimination of responding by time out, may all be regarded as aversive, at least for the pigeon. Rate increases in the constant component of a multiple schedule are assumed to reflect the emotional states generated by such aversive stimuli. However, contrast may also appear as a reduction of rate in the constant component when rate increases in the varied component. For instance, in Reynolds' (1963) Exp 1, increasing the frequency of reinforcement from 13 to 53 per hr in the presence of a green key produced rate increases in green, and rate decreases on an alternated red key, which was correlated with a constant 20 reinforcements per hr. It is not clear that such decreases are readily accounted for by similar emotional mechanisms.

A third and somewhat more speculative account of contrast has been proposed by Williams (1965*a, b*). He notes, as does Reynolds (1961*a*), that operant contrast effects are similar to induction phenomena in respondent

conditioning. Pavlov (1927, Lecture XI) showed that when a positive conditioned stimulus (CS) was immediately preceded by a well-established negative CS, anticipatory salivation in the positive CS had a shorter latency and greater amplitude than when the positive CS was presented alone. He called this phenomenon positive induction, and inferred the inverse phenomenon of negative induction—reduced salivation due to prior presentation of a positive CS—from data on the abolishment of differential conditioning. Pavlov interpreted these induction effects as reflecting an enhanced excitatory process when an inhibitory stimulus was terminated, and intensified inhibition when an excitatory stimulus was terminated. Such excitatory or inhibitory processes were presumed to be conditioned to the positive and negative CSs through the operations of pairing and withholding the unconditioned stimulus for the reflex under study.

Operant contrast may be interpreted in an analogous fashion. The component stimuli of a multiple schedule may be assumed to become relatively excitatory or inhibitory as a result of the frequencies with which they are correlated with reinforcement. An increased response rate in a VI stimulus after exposure to extinction in the alternated stimulus is interpreted as reflecting enhanced excitation after inhibitory effects conditioned to the extinction stimulus are terminated. Rate decreases after exposure to more frequent VI reinforcement would indicate enhanced inhibition after relatively greater excitation. As Williams (1965*a*) notes, such an account obviously depends on the independent specification of the excitatory or inhibitory properties of the component stimuli. The concept of inhibition, as used in the Pavlovian induction account of contrast, differs from the emotional processes described by Terrace (1962). Skinner (1938, p. 233) has pointed out that it may be difficult to separate conditioned inhibition from conditioned emotional responses: both may result from non-reinforcement and have similar behavioral effects. Jenkins (1965) has proposed that inhibition be defined by a generalization gradient of extinction along a continuum orthogonal to that on which the positive and negative discriminative stimuli are defined. Demonstrations of such gradients (*e.g.*, Honig, Boneau, Burstein, and Penny-

packer, 1963) have involved successive discrimination training procedures which normally produce contrast. Beyond this, the relations between these gradients and contrast effects are not yet clear.

Despite these uncertainties, an account of contrast phenomena in terms of interactions between excitation and inhibition may be of some heuristic value. Pavlov (1927, Lectures XI and XII) found that the magnitude of positive induction effects depended on the time elapsing from offset of the negative CS to onset of the positive CS, being greatest when the positive CS was presented immediately. By analogy, the response rate in a constant VI component might depend on the time separating that component from exposure to an extinction stimulus, or alternatively, the response rate within a single VI component might depend on the time since component change.

Several operant experiments have demonstrated such effects. Boneau and Axelrod (1962) used a successive discrimination procedure to expose pigeons to a stimulus correlated with extinction for 1 min, followed by seven 1-min exposures to a stimulus correlated with VI. Stimulus presentations were separated by a 10-sec time out. Rate decreased systematically in the VI stimulus as a function of the ordinal number of the VI period after extinction. In a similar experiment, Terrace (1966) presented pigeons with either a VI or an *ext* stimulus in random order, using 1-min periods separated by a brief time out. He found that the rate in the VI stimulus was higher if it followed *ext* than if it followed VI. If the discrimination was learned without errors, VI rates were lower and did not depend on the preceding stimulus. Also, Catania and Gill (1964) exposed pigeons to a multiple fixed interval (FI) *ext* schedule, and found that response rate was markedly higher in the first of several FI cycles following an *ext* stimulus than in subsequent cycles.

All these experiments describe effects analogous to positive induction. Williams (1965a) has reported data from a running wheel experiment with rats and fixed or variable time schedules of brain stimulation reinforcement which clearly demonstrate the analog to negative induction. Immediately after the change from a multiple schedule component with high reinforcement frequency to one with rel-

atively infrequent reinforcement, the proportion of time spent running was low, followed by an increase to an intermediate level. The magnitude of the effect depended on the duration of the preceding high-reinforcement-frequency component. The finding has been replicated with food reinforcement by Williams and Bernheim (in preparation).

For the purposes of the present paper, such changes in response rate within a constant schedule component, or repeated presentations of the constant component after exposure to the varied component, will be termed transient contrast effects if the initial rate differs from the terminal rate in a direction which increases the difference between levels of responding maintained by the component schedules. It is intended that they be distinguished from sustained contrasts, which also increase rate differences, in that the latter are measured by shifts in the level of responding over successive cycles of the multiple schedule, commonly from one session or one procedure to the next. The distinction may be clarified by the hypothetical example sketched in Fig. 1. The left portion of the upper panel indicates the VI baseline rate. At *a*, a stimulus correlated with extinction is introduced and a low rate ensues. At *b*, the VI stimulus is presented again. The enhanced initial rate in the

Fig. 1. Transient and sustained contrast effects in multiple schedules. See text.

second presentation of the VI stimulus is a positive transient contrast effect; the increase in mean rate from the first to the second presentation is the sustained contrast effect. Examples of negative transient and sustained contrasts are similarly presented in the lower panel, where a stimulus correlated with more frequent VI reinforcement is inserted between the first and second presentations of the constant VI component.

It can be argued that the contrast effects indicated by overall rate measures result from transient contrasts. Enhanced responding early in a stimulus associated with reinforcement will obviously increase the mean rate. Such an effect appears occasionally in the cumulative records presented by Reynolds (1961a) and Terrace (1963a). It also appears in responding following a stimulus associated with punishment (Brethower and Reynolds, 1962). However, the latter authors have interpreted their finding as a suppression late in the unpunished component resulting from the adventitious correlation of responding with onset of the stimulus correlated with punishment. Similarly, responding late in a VI component might be suppressed by extinction stimulus onset. The opposite case can be made for negative transient contrasts. In summary, there is evidence that transient contrast effects exist in multiple schedules, but it is unclear to what extent they are due to adventitious reinforcement or suppression of responding at the end of the components, and to what extent sustained contrasts result from them.

The present experiments investigate transient contrasts in a procedure apparently free from contaminating effects, and examine their relations to sustained contrasts.

METHOD

The following features were common to all three experiments.

Subjects

Adult male white Carneaux pigeons with no experimental histories were maintained and run at 80% of their free-feeding weights, ± 15 g.

Apparatus

The response chamber (Lehigh Valley #1519C) was equipped with a standard grain

magazine, and a response key which could be transilluminated with red, green or white light. Standard electro-mechanical programming and recording apparatus was in a separate room.

Procedure

All procedures involved multiple schedules of reinforcement, in which different key colors were correlated with separate schedules of reinforcement. Reinforcement always consisted of 3-sec access to a hopper containing mixed grain. Reinforcement availability was programmed by arithmetic variable interval tapes, which ran only during the components with which their schedules were correlated. Any reinforcement made available but not collected during a given component was cancelled.

EXPERIMENT I

This sought to determine whether transient contrast effects would appear in a conventional two-ply multiple schedule.

Procedure

After shaping and 100 regular reinforcements for pecking a white key, Birds 15, 16, and 17 were exposed to mult VI 2 (green key) VI 6 (red key) for 20 sessions. Stimuli and schedules alternated every 3 min. The first six sessions were 60 min duration, the remainder 90 min. Sessions were run five days per week.

Results

Figure 2 shows response rates in successive 30-sec periods of red and green for each of the last four sessions for Birds 15 and 17. Both birds had a lower overall rate in the VI 6 (red) stimulus than in the VI 2 (green) stimulus. Both reliably showed transient contrast effects. When the key color changed from green to red, initial rate was low, then increased to a stable level. When key color changed from red to green, rate abruptly increased, then decreased to a stable level above the final level in red. The first of these effects is negative transient contrast and the second, positive transient contrast. Sustained contrast was not evaluated.

Overall rates for Bird 16 differed only slightly in the two stimuli, and the difference

Fig. 2. Rate of responding in successive 30-sec periods of mult VI 6 VI 2, with 3-min components. Functions are plotted separately for the final four of 20 sessions.

disappeared with continued training. No transient contrast of either type was apparent. However, in an experiment mentioned by Williams (1965*b*) and described in personal communication, positive and negative transient contrasts were obtained in four out of four pigeons on a mult VI 1.5 VI 15 schedule. This suggests that inter-subject reliability may be improved by increasing the difference between the reinforcement frequencies in the two components of the schedule.

These transient contrasts are opposite in direction to effects expected on the basis of Pliskoff's (1961) results. Pliskoff demonstrated that rate increased in a warning stimulus preceding a change to a schedule component with lower reinforcement density, and decreased in a warning stimulus preceding a higher reinforcement density. If the passage of time in a component serves as a warning stimulus for onset of the next component, rate should decrease during exposure to VI 6, and increase during exposure to VI 2. Pliskoff's experiment used 15-min components, and involved appreciably more exposure to the general procedure. An analysis of rate changes in longer components during prolonged training

should clarify the relations between these findings.

EXPERIMENT II

This attempted to demonstrate the transients observed in Exp I within a single stimulus correlated with a constant frequency of reinforcement, under conditions designed to minimize adventitious contingencies based on component changes. The basic notion was to program the component stimuli of a three-ply multiple schedule in various orders, and to examine behavior in one component as a function of the preceding component.

Procedure

After shaping and about 100 regular reinforcements for pecking in green, white, and red, Birds 3, 8, and 11 were exposed to a three-ply multiple schedule indicated as Procedure A in Fig. 3. For Bird 11, each schedule cycle consisted of a 2-min presentation of a red key, which was correlated with VI 8 min reinforcement, followed by a 10-sec time out, during which the key was dark, and preceded by a 2-min presentation of either green or white. Green was correlated with VI 2 min reinforcement, and white with extinction. Green and white were presented in alternate cycles. Twelve sessions of 24 cycles were run on consecutive days.

This general procedure was replicated with Birds 3 and 8. To eliminate any possible effects of alternation, cycles started with green or white in random sequence except that green and white occurred equally often in blocks of eight cycles. Green was correlated with VI 1 min reinforcement, red with VI 5, and white with extinction. Green or white stimuli were presented for 100 sec followed by

Fig. 3. Diagram of procedures in Exp II and III.

75-sec periods of red, which always ended in a 10-sec time out. Eighteen daily sessions of 32 such cycles were run. Birds 3 and 8 were then exposed to eight additional sessions on Procedure A with VI 10 rather than VI 5 in red, to reduce their response rates in red. Then, the extinction stimulus (white) was removed, leaving Procedure B of Fig. 3, with VI 1 in green and VI 10 in red. Finally, green was replaced by the extinction stimulus, white, as in Procedure C of Fig. 3, with VI 10 in red. Procedures B and C were in effect for four 32-cycle sessions each. The purpose of these procedure changes was to demonstrate sustained contrast effects by varying the schedule alternated with VI 10 across sessions.

Results

Bird 11. Response rates were computed separately for successive 20-sec periods in red following green and in red following white for each session. Overall rates in green and white were also determined. These data are shown in Fig. 4 for sessions 10 through 12. When red was presented after exposure to green, which controlled a high rate, the initial rate was low, followed by an increase to a fairly stable level. When red was presented after exposure to white, in which little responding occurred, rate was initially high, then declined to a level approximately the same as the terminal rate in red following green. There was some variability in the level of responding from day to day, but the pattern within the red component was quite constant over this three-day sample. Development of this performance could not be traced

because of recording apparatus failures. However, it is clear that this procedure made it possible to observe positive and negative transient contrasts in a constant schedule component, depending on the schedule of reinforcement correlated with the immediately preceding stimulus.

Birds 3 and 8. Response rates were computed separately for successive 15-sec periods in red (VI 5) following green (VI 1), and in red (VI 5) following white (*ext*), for each daily session. Overall rates in green and white were also determined. These data are presented in Fig. 5 for sessions typical of various stages in the development of performance on Procedure A. Negative transients following green, and positive transients following white, appeared by session 6 for both birds. As training progressed, the positive transient became less reliable, and had virtually disappeared in session 12, although the negative transient following green remained reliable for both birds. The data for session 18 show that the patterns of responding in red had become largely independent of the preceding stimulus. Despite the variability of the pattern of rate changes within the red (VI 5) component, the response rate in the first 15 sec of red after green was lower than that during the first 15 sec of red after white from session 2 through session 18 for both birds. Differences in terminal rate were smaller and less consistent in direction.

When the reinforcement schedule correlated with red was changed from VI 5 to VI 10, both birds exhibited reliable negative transients and a clear positive transient reappeared in the performance of Bird 3. These effects are illustrated in panel A8 of Fig. 6, which is based on the data for the eighth session on Procedure A with VI 10 in red. When Procedure B was instituted, the overall rate in green (VI 1) decreased in sessions B1 through B4 (Bird 8 was overweight on the day scheduled for session B2). This was accompanied by decreased responding in red for Bird 3, and a less marked decrease for Bird 8. The negative transients in red remained generally reliable.

When the green (VI 1) stimulus was replaced by white (*ext*) in Procedure C, Bird 3's rate immediately increased in red, appearing with a clear positive transient in session C1. Responding in red remained substantially

Fig. 4. Performance of Bird 11 on Procedure A for sessions 10 through 12. Responding in red (VI 8) is broken down into six successive 20-sec periods following green (G, VI 2) or white (W, *ext*). Points over G and W represent overall rates in those stimuli.

Fig. 5. Development of performance on Procedure A for Birds 3 and 8. Responding in red (R, VI 5) is broken down into five successive 15-sec periods following green (G, VI 1, open points) or white (W, *ext*, filled points). Single points over G and W represent overall rates in those stimuli.

above the level in Procedure B throughout sessions C1 through C4, despite the disappearance of the positive transient contrast effect. For Bird 8, the rate increase in red was more gradual, but by session C2 was clearly above the level maintained in Procedure B. Thus, both birds evidenced sustained contrast effects: when the schedule component alternated with red (VI 10) was changed from green (VI 1) to white (*ext*), with a consequent abrupt decrease in the response rate in the alternated component, responding in the constant component increased. The behavior in green (VI 1) was also shown to depend on the presence of

white (*ext*) in the experimental situation: removing white in sessions B1 through B4 resulted in decreases in overall rate in green for both birds.

EXPERIMENT III

This experiment attempted to determine whether the differences in responding in red on Procedure A were attributed to differential rate of responding or to differential reinforcement frequency in green and white by the use of DRO (differential reinforcement of other behavior, *cf.* Reynolds, 1961a) in green.

Fig. 6. Final performances of Birds 3 and 8 on Procedure A (A8), and performances on successive sessions of exposure to Procedures B (B1-B4) and C (C1-C4). Responding in red (R, VI 10) is broken down into five successive 15-sec periods following green (G, VI 1) or white (W, *ext*). Single points over G and W represent overall rates in those stimuli. Rates in red following green are given by open points in sessions A8 and B1-B4. Rates in red following white are given by filled points in sessions A8 and C1-C4.

Procedure

Two naive pigeons, 24 and 25, were given special training to insure a low frequency of pecking in green. They were shaped to peck a red key, and their response rates were built up by gradually shifting to a fixed ratio (FR 15) schedule. Green was then introduced when the birds' positions made pecking unlikely, and reinforcement was delivered immediately so that no keypeck could occur. The key color was changed back to red, and FR reinforcement was continued. After several such cycles, it became possible to lengthen the duration of green and to deliver several reinforcements at variable intervals for behavior other than pecking. Despite these precautions, both birds pecked six times in green. After rapid pecking in red and no pecking in green was well established, white was introduced for 1-min periods after either red or green. No reinforcement was ever presented in white. One bird pecked twice in white, the other not at all. This training was completed in a single session lasting about 2 hr.

Two days later, training was initiated on Procedure A with a VI 1 DRO contingency in green, VI 5 in red, and *ext* in white. Throughout the 100-sec presentation of green, the VI 1 reinforcement tape ran continuously, and the grain hopper was presented with no contingency on responding. If a peck did occur, it was followed immediately by a 10-sec time out, during which the key light was off and the tape stopped.

Key-pecking in red was not maintained on initial exposure to VI 5, and additional training on VI 30 sec in red was necessary for the first few cycles of each of the first three sessions before lengthening the VI gradually. Pecking in red was easily disrupted by slight noises, so the experiment was run at night when the building was quiet. After the third such session responding was maintained satisfactorily. The birds were then exposed to Procedure A for 24 sessions. After this training, Procedure B was run for three sessions, followed by Procedure C for four sessions. Sessions always consisted of 32 schedule cycles and were run on consecutive nights.

Results

The rates of key-pecking in green and white were low throughout the experiment, averaging

much less than one response per cycle. The rate of key-pecking in successive 15-sec periods of red following green or white for sessions 10 through 12 on Procedure A is presented in Fig. 7. Both birds showed orderly increases in rate after exposure to green (VI 1 DRO), and Bird 24 exhibited decreases after exposure to white (*ext*). Initial rates following green were always lower than those following white for both birds from session 3 through session 19, but terminal rates were about the same.

As training progressed, the rate changes in red became somewhat less orderly and less clearly dependent on the immediately preceding schedule component. Final performance on Procedure A, in panel A24 of Fig. 8, shows that rate increases in red (VI 5) after exposure to green (VI 1 DRO) were still apparent but that the pattern of responding in red (VI 5) after white (*ext*) indicated little if any positive transient contrast. When white was removed, leaving Procedure B (Fig. 8, sessions B1 through B3), the overall level of responding in red after green decreased slightly for both birds. When green was removed and replaced by white in Procedure C, Bird 24's rate immediately increased in red, with a clear positive transient contrast appear-

Fig. 7. Performances of Birds 24 and 25 on Procedure A for sessions 10 through 12. Responding in red (VI 5) is broken down into five successive 15-sec periods following green (G, VI 1 DRO) or white (W, *ext*). Points over G and W represent overall rates in those stimuli.

ing in session C1. Its rate remained well above that in Procedures A and B, despite the absence of positive transient contrasts, in sessions C2 through C4. For Bird 25 the level of responding in red increased somewhat more slowly, but in sessions C2 through C4 it was clearly above the rate maintained in Procedures A and B. There was no evidence of positive transient contrast for this bird.

In summary, this experiment reproduced the major effects of Exp II in the absence of responding in green.

DISCUSSION

When a stimulus correlated with variable interval reinforcement is presented in the context of a multiple schedule, responding in that stimulus depends on the schedule of reinforcement correlated with the immediately preceding stimulus. If the preceding frequency of reinforcement is higher, the initial rate is low, followed by an increase with continued exposure to the stimulus. If the preceding frequency of reinforcement is lower, the reverse occurs. These effects, which we have called transient contrasts, are reliably observed at an intermediate stage of training, later becoming less orderly (see also Boneau and Axelrod, 1962). These effects depend on differential reinforcement frequency, rather than on differential rate of occurrence of the measured response, and are apparently not

the result of adventitious reinforcement or suppression of terminal rates (see also Williams, 1965a).

The finding of Exp III that rate increased in red (VI 5) after exposure to green (VI 1 DRO) does not qualify as a negative transient contrast, strictly speaking, since the rate in green was near zero. However, the effect was functionally similar to the negative transient contrasts observed in Exp II, and is treated similarly in this discussion.

Sustained contrast effects, such as those reviewed in the introduction, were demonstrated in Exp II and III. When the schedule alternated with a constant VI in red was changed from VI 1 (Procedure B) to *ext* (Procedure C), the rate in red increased. The effect was sudden for one bird in each experiment, and gradual for the other.

The present procedure was unusual in that both the stimulus and the schedule in the alternated component were changed when shifting from Procedure B to Procedure C. The accounts of contrast by Reynolds and Terrace were not specifically formulated to deal with this case, but it is of interest to apply them here. In Exp III, the contrast effect was obtained with no change in responding in the alternated component stimuli, either at the time of the procedure change or at any time in the experiment. In terms of Terrace's (1966) account, this suggests that reduction in rate of the measured response may not be a

Fig. 8. Final performances of Birds 24 and 25 on Procedure A (A24), and performances on successive sessions of exposure to Procedures B (B1-B3) and C (C1-C4). Responding in red (R, VI 5) is broken down into five successive 15-sec periods following green (G, VI 1 DRO) or white (W, *ext*). Single points over G and W represent overall rates in those stimuli. Rates in red following green are given by open points in sessions A24 and B1-B3. Rates in red following white are given by filled points in sessions A24 and C1-C4.

necessary condition for the emotional effects responsible for contrast. Our results are readily explained by Reynolds' (1961a) suggestion that contrast depends on changes in relative reinforcement frequency: in Procedure B, only a small fraction of all reinforcements were available in red; in Procedure C, all reinforcements were available in red.

In Exp II, the overall level of responding in green (VI 1) was found to depend on the presence of an extinction component in the procedure. When the extinction component was removed in changing from Procedure A to Procedure B, the rate in green decreased. The finding is quite similar to that of Terrace (1963a), who showed that rate in S+ decreased when an S- to which errors had occurred was removed from the procedure. This rate decrease may be attributed to the absence of emotionality associated with extinction when the extinction stimulus is not presented. If so, the rate-enhancing effects of emotionality cannot depend on immediately prior stimulation, since green was always preceded by 75-sec exposure to red (VI 5) and a 10-sec time out in both Procedures A and B.

It is not clear that the rate decrease in green can be explained by changes in relative reinforcement frequency, since the reinforcement schedules in both red and green remained the same, and the relative number of reinforcements actually increased. However, it may not be appropriate to calculate relative reinforcement when components are added to or removed from a multiple schedule. In summary, the overall rate changes in the present experiments do not permit a choice between the general formulations of Reynolds and Terrace.

The final point concerns the relations between transient and sustained contrasts. It is clear in Fig. 4, 5, and 7 that initial rates within a constant VI component depend on the immediately preceding component, but that the levels of responding late in the constant component tend to be the same. On the other hand, Fig. 6 and 8 demonstrate that the level of responding in a constant VI component may be shifted by changing the alternated schedule component, without any systematic change in the pattern of responding within the constant component. The abruptness of changes in the level of responding across procedures may be correlated with

transient contrasts: Birds 3 and 24 showed abrupt changes and positive transient contrasts when the procedure was changed from B to C. However, the sustained contrast effects outlasted the transients as training continued. Boneau and Axelrod (1962) have reported similar data. It therefore appears that sustained and transient contrasts may be at least partly independent.

Our results are closely related to those of Terrace (1966, Fig. 19) who found that the response rate in a VI stimulus in a multiple schedule with components presented in random order was higher if that stimulus followed extinction than if it followed VI. This rate difference vanished after 18 sessions of training for the individual bird shown, even though the sustained contrast, relative to a bird trained without errors, persisted. (Terrace also reports that in another experiment overall rate eventually declined to its original level, but only after two or three months of continued training.)

Terrace (1966, p. 321) specifically suggests that "... there seem to be at least two factors which contribute to the increase in rate of responding to S+. One is the value of the preceding stimulus and the other is the fact that the organism has been exposed to a differential reinforcement procedure."

This accords with our interpretation of the relations between transient and sustained contrasts.

The transient contrasts in our experiments are analogous to Pavlovian induction phenomena, both in their brief duration within a component and in their impermanence with continued training (Pavlov, 1927, Lecture XI). The negative transient depends on occurrence of relatively frequent reinforcement in the preceding component, rather than occurrence of the measured operant, as Williams (1965a) has also shown. Stimuli associated with non-contingent reinforcement may increase rates of subsequently acquired operant behavior when presented during extinction (Estes, 1948). Conversely, stimuli correlated with extinction may reduce the rate of responding when presented in compound with a former VI stimulus during experimental extinction (Cornell and Straub, 1965). We are inclined to regard such stimuli as possessing excitatory

or inhibitory properties, in the sense of Pavlovian theory, because their effects cannot readily be explained by differential reinforcement of operant behavior. The transient contrasts in the present experiments are thus interpreted as the short-term after-effects of excitation or inhibition, depending on the frequency of reinforcement in the preceding stimulus. This interpretation is by no means forced, and one could equally well conclude that transient contrasts reflect some special short-term emotional processes. Since any such processes would still have to be measured independently, and since there is some precedent for invoking and measuring excitation and inhibition in operant discrimination (Jenkins, 1965), we prefer this interpretation. In any event, something in addition to these short-term effects must be responsible for the sustained contrasts in the present experiments, but it is not clear whether these sustained contrasts are best explained by changes in general emotionality or relative reinforcement.

REFERENCES

- Boneau, A. and Axelrod, S. Work decrement and reminiscence in pigeon operant responding. *J. exp. Psychol.*, 1962, **64**, 352-354.
- Brethower, D. M. and Reynolds, G. S. A facilitative effect of punishment on unpunished behavior. *J. exp. Anal. Behav.*, 1962, **5**, 191-199.
- Catania, A. C. Behavioral contrast in a multiple and concurrent schedule of reinforcement. *J. exp. Anal. Behav.*, 1961, **4**, 335-342.
- Catania, A. C. and Gill, C. A. Inhibition and behavioral contrast. *Psychon. Sci.*, 1964, **1**, 257-258.
- Cornell, H. M. and Straub, H. A technique for demonstrating the inhibitory function of S^A . *Psychon. Sci.*, 1965, **3**, 25-26.
- Estes, W. K. Discriminative conditioning. II. Effects of a Pavlovian conditioned stimulus upon a subsequently established operant response. *J. exp. Psychol.*, 1948, **38**, 173-177.
- Friedman, H. and Guttman, N. Further analysis of the various effects of discrimination training on stimulus generalization gradients. In *Stimulus generalization* (D.I. Mostofsky, ed.). Stanford: Stanford University Press, 1965.
- Honig, W. K., Boneau, C. A., Burstein, K. R., and Pennypacker, H. S. Positive and negative generalization gradients obtained after equivalent training conditions. *J. comp. physiol. Psychol.*, 1963, **56**, 111-116.
- Jenkins, H. M. Generalization gradients and the concept of inhibition. In *Stimulus generalization* (D.I. Mostofsky, ed.). Stanford: Stanford University Press, 1965.
- Pavlov, I. P. *Conditioned reflexes* (translated by G. V. Anrep). London: Oxford University Press, 1927.
- Pliskoff, S. Rate-change effects during a pre-schedule-change stimulus. *J. exp. Anal. Behav.*, 1961, **4**, 383-386.
- Reynolds, G. S. Behavioral contrast. *J. exp. Anal. Behav.*, 1961a, **4**, 57-71.
- Reynolds, G. S. An analysis of interactions in a multiple schedule. *J. exp. Anal. Behav.*, 1961b, **4**, 107-117.
- Reynolds, G. S. Relativity of response rate and reinforcement frequency in a multiple schedule. *J. exp. Anal. Behav.*, 1961c, **4**, 179-184.
- Reynolds, G. S. Contrast, generalization, and the process of discrimination. *J. exp. Anal. Behav.*, 1961d, **4**, 289-294.
- Reynolds, G. S. Some limitations on behavioral contrast and induction during successive discrimination. *J. exp. Anal. Behav.*, 1963, **6**, 131-139.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century, 1938.
- Terrace, H. S. Discrimination learning with and without "errors". *J. exp. Anal. Behav.*, 1963a, **6**, 1-27.
- Terrace, H. S. Errorless transfer of a discrimination across two continua. *J. exp. Anal. Behav.*, 1963b, **6**, 223-232.
- Terrace, H. S. Stimulus control. In *Operant behavior: areas of research and application* (W. K. Honig, ed.). New York: Appleton-Century-Crofts, 1966.
- Williams, D. R. Negative induction in behavior reinforced by central stimulation. *Psychon. Sci.*, 1965a, **2**, 341-342.
- Williams, D. R. Classical conditioning and incentive motivation. In *Classical conditioning* (W. F. Prokasy, ed.). New York: Appleton-Century-Crofts, 1965b.
- Williams, D. R. and Bernheim, J. W. In preparation.

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