The Development of Behavioral Contrast in Human Subjects

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THE DEVELOPMENT OF BEHAVIORAL CONTRAST
IN HUMAN SUBJECTS

by

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A problem of current and historical interest has been the description and analysis of behavior interactions. An interaction may be defined as a change in behavior under one set of conditions produced by environmental changes under another set of conditions.

The earliest systematic analysis of interactions appears in the work of Pavlov (1927). He observed that a greater magnitude of salivation was elicited during S+ trials which followed S- trials. Pavlov labeled this phenomenon "positive induction." Skinner (1938), in an investigation of response rate changes during the formation of an operant discrimination, subsequently referred to such changes as "contrast."

Reynolds (1960a), studying interactions explicitly, referred to them as examples of "behavioral contrast"

"The change in behavior is called contrast when the change in the rate of responding during the presentation of one stimulus is in a direction away from the rate of responding generated during the presentation of the other stimulus." (p. 57)

Increases in response rate during one component and decreases during a second component produced by some procedural change during the second component describes positive contrast; the inverse is commonly referred to as negative contrast (Reynolds, 1961b).
Interactions also include changes in responding in one component of a multiple schedule in the same direction as changes in the second component. These changes are referred to as induction effects and may also be either positive or negative (Reynolds, 1963).

Nearly all free-operant studies of contrast have utilized multiple schedule procedures. Assessment of response rate changes has been facilitated by two methods of comparison. In a between-session analysis, changes in response rate are compared across sessions and/or experimental conditions. In Reynolds (1961a) study for example, a between-session analysis of rate changes was accomplished by comparing response rate during the constant VI component of a mult VI VI schedule with the same VI component when the schedule was shifted to mult VI EXT. Comparisons of response rate can also be made between components in each session and secondly, across temporal intervals within an individual component. Changes in rate occurring between components are referred to as sequential contrast effects (Terrace, 1966; O'Brien, 1968), changes in rate within a single component, as transient contrast effects (Nevin and Shettleworth, 1966).

Generality with respect to response topography, subject, and reinforcer has been shown in several studies of interaction phenomena. Positive contrast has been reported with pigeons and key pecking, utilizing grain as a reinforcer.
(Reynolds, 1961a, Bloomfield, 1967a). Using rats, lever-pressing, and food pellets, Hitzing and Schaeffer (1968) reported positive contrast in mult VI DRL schedules and Williams (1965) found transient negative contrast using rats wheel running on fixed or variable time schedules of brain stimulation reinforcement. O'Brien (1968) demonstrated sequential contrast effects with humans, button pushing for money.

Behavioral interactions have been studied with a variety of experimental procedures. One method initially used by Reynolds is the manipulation of the absolute reinforcement frequency in one component of a multiple schedule.

Reynolds (1961a, 1961b) and Bloomfield (1967) have both studied the effects of changing the absolute reinforcement frequency on the production of contrast. Reynolds has reported positive contrast with multiple VI, VR, FI, and FR schedules of reinforcement. His research showed that the rate of responding during the constant component of a multiple schedule is proportional to the relative rate of reinforcement in that component. Bloomfield (1967), utilizing a mult VI FR baseline, found similarly that response rate in the VI component was determined by the reinforcement density in that component relative to the reinforcement density in the FR component. Time-out procedures have also been used to manipulate relative reinforcement frequency. Reynolds (1961a) reported positive contrast when a mult VI
3 min VI 3 min schedule was changed to mult VI 3 min TO. Here again the response rate in the VI component was a function of a decrease in the absolute reinforcement frequency during the TO component.

While manipulating absolute reinforcement frequency has reliably produced behavioral contrast, it recently has become possible to separate the individual contributions of reinforcement frequency and rate of response. Holding reinforcement frequency constant while manipulating response rate in one component has been a method of determining the role of response rate changes in the production of contrast.

The addition of a punishment contingency in one component of a multiple schedule was used by Brethower and Reynolds (1962) and Terrace (1968) to produce positive contrast. They punished each response by electric shock during the variable component. In the Brethower and Reynolds study the magnitude of the contrast effect was found to be an increasing function of shock intensity. However, the frequency of obtained reinforcements decreased as the rate of punished responding decreased in the variable component. The effects of punishment were thus confounded with the effects of decreasing reinforcement frequency. Terrace, holding frequency of reinforcement constant found contrast effects in the constant VI 1 min component of a multiple schedule when each response during the variable component was punished by electric shock. The shock intensity was adjusted daily to
insure that the decreased rate of punished responding was sufficient to produce all of the scheduled reinforcements. Thus since reinforcement frequency was held constant, Terrace attributed contrast to the reduction in rate of responding during one member of a pair of alternating discriminative stimuli. However, Terrace made no provision in his analysis for the effects of the punishment contingency which may have been confounded with the reduction he observed in response rate.

Two further procedures have been used to reduce response rate in one component of a multiple schedule. The addition of a DRL schedule has been used by Terrace to produce decreased response rates while reinforcement density remained constant in both components. Terrace (1968) using a mult VI 1 min baseline schedule reduced rate of responding in one component by substituting a DRL contingency. The value of the DRL schedule ranged from 6 to 8 sec and was modified daily in order to keep the number of reinforcements in the VI and DRL components as equal as possible. With the DRL in effect, positive contrast was demonstrated in the constant VI component. Weisman (1969) using the same procedure reported similar effects with mult VI DRL schedules.

Brownstein and Newsom (1970) used a cue procedure to reduce response rate in one component of mult FI FI schedules. The cue procedure consisted of illuminating a lamp located on the intelligence panel 3 sec prior to the reinforcement
availability. This procedure produced a positive contrast effect—rate of responding in the cued component decreased and the rate of responding in the uncued component increased. When the cue was removed negative contrast was observed. Rate of responding in the component from which the cue had been removed increased, and rate of responding in the unchanged component decreased. Throughout the experiment, rates of reinforcement in both components were held constant. Reynolds and Limpo (1968) investigated the development of contrast in a multiple schedule where responding in each component was reinforced on a DRL schedule. Responding during one component was then reduced by the addition of an IRT clock. Sequential cue lights indicated successive five sec IRT intervals. The addition of the IRT clock resulted in decreased rate of responding and an increased frequency of reinforcement in the changed component. However, positive contrast occurred in the unchanged component even though the rate of reinforcement increased in the clock component. The most important generative factor for the production of contrast, therefore, appeared to be the reduction in rate produced by the addition of the IRT clock.

Common to all these examples is the reduction of the rate of responding during one discriminative stimulus of a multiple schedule. In this respect, contrast and the peak-shift phenomenon are both taken to be consequences of the
subjects learning not to respond or to respond less to that stimulus (inhibition). Where inhibition does not occur as in "errorless" discrimination training (Terrace, 1965a, 1966a), contrast and peak-shift do not appear.

Bloomfield (1969) has suggested a more general explanation to account for behavioral contrast. He maintains that a basic determinant of contrast is a change for the worse in the conditions of one component of a multiple schedule. His analysis of changes constituting a worsening would include reduction in absolute reinforcement frequency, electric shock, TO, inhibition, or any other procedural variation which may be reduced ultimately to a worsening of conditions. This explanation also may help resolve the difficulties found by Reynolds and Limpo (1968) in their discussion of the multiple determination of contrast in terms of reduction in response rate and changes in reinforcement frequency. In Bloomfield's view the DRL schedule requires the bird to temporally space or inhibit his responding—a case of worsened conditions.

Hitzing (1970), proposes that contrast may result from changes in the aversive or reinforcing characteristics of one component relative to another. If shock or DRL contingencies are added to one component, the conditions present in the unchanged component would be relatively more reinforcing; conditions in the changed or "worsened" component relatively
more aversive. In any event, final resolution of the role of relative aversiveness should be determined by independent means such as a concurrent test of schedule preference.

While schedule interactions have been extensively studied with infrahuman organisms, the literature is almost barren with respect to studies of behavioral contrast with human subjects. O'Brien (1968) has reported evidence for sequential contrast effects with two institutionalized girls. In this study both subjects were exposed to a mult VI EXT schedule of reinforcement in which five min periods of VI and five min periods of extinction were presented in a random fashion instead of simple alternation. This schedule generated sequential contrast effects not unlike those reported by Terrace (1966): response rates during VI components following extinction components were higher than the rates during VI components following other VI components. Like Terrace's data the sequential contrast effects were transient, being most evident during early sessions and disappearing during the remaining sessions. The production of between-session contrast was not demonstrated in this study despite the presence of sequential effects. Between-session contrast effects of this sort will be evident only when there is a shift from non-differential to differential reinforcement conditions within a multiple schedule. The analysis of between-session contrast is impossible without a pre-experimental baseline by which a comparison between S+ and S- responding can be made.
On the basis of O'Brien's findings the generality of behavioral contrast phenomena with human subjects has not been clearly established. The focus of this investigation was to systematically extend the study of the contrast phenomenon observed in lower animals to human operant behavior.
METHOD

Subjects

The subjects were three experimentally naive institutionalized mental patients from Kalamazoo State Hospital. Subject D.C. was 34 years of age and had been hospitalized for eight years. He was diagnosed as "mentally deficient with behavioral reaction," and received 100 mg of Dilantin per day. Subject N.S. was 50 years of age and had been hospitalized for eight years. He was diagnosed as "schizophrenic reaction: Catatonic type," and received 800 mg of Thorazine per day. Subject D.E. was 51 years of age, hospitalized for twenty years and diagnosed as "schizophrenic reaction: Paranoid type," receiving 400 mg of Thorazine per day.

Apparatus

The test apparatus was a specially constructed 4' x 8' x 8' two lever plywood chamber equipped with two Gerbrands universal feeders. The centers of the two levers (Lindsley Manipulandum) were 56" apart and 35" above the chamber floor. Both feeders were located 6" from their respective levers. Directly above each lever was a 6" x 18" translucent plexiglass panel which could be illuminated by any combination of red, green, or amber stimulus lights. The floor of the chamber was carpeted and a chair was mounted equidistant from both levers.
houselight which provided general illumination was mounted on the ceiling. Appropriate electromechanical equipment was used to program the various schedules and record the behavior. All recording and control apparatus was housed in a nearby room.

**Procedure**

The subjects were instructed to operate the left lever initially and their responses were reinforced with pennies on a mult VI 30 sec VI 30 sec schedule. This schedule was gradually changed until responding on the lever was maintained by a mult VI 1 min VI 1 min schedule. The terminal baseline schedule (mult VI 1 min VI 1 min) was a two-ply schedule consisting of 24 two-minute components presented in a relatively random sequence with a maximum of three successive presentations of either stimulus (red or green). Each stimulus condition was presented a total of 12 times during each session. A three second time out also followed each component. During time out, the stimulus lights and houselight were extinguished and responses were ineffective in producing reinforcement.

Following baseline stabilization, the following procedural changes were made:

(1) **Extinction - Single lever.** During this condition the schedule of reinforcement was changed from mult VI 1 min VI 1 min to mult VI 1 min EXT. The subjects had access to one lever during this schedule, with the VI ply (green stimulus light) randomly alternating with the extinction ply (red stimulus light).
(2) Extinction - Two lever. Following mult VI 1 min EXT in the above condition the schedule was changed back to mult VI 1 min VI 1 min. Subjects now, however, responded on different levers during each ply of the multiple schedule. The subject was now required to move from one side of the chamber to the other in order to respond appropriately. Following stabilization of response rates; the schedule was again switched to mult VI 1 min EXT. The VI ply now was associated with the left green stimulus and left bar; the extinction ply with the right red stimulus and right lever. The schedule was ultimately returned to mult VI 1 min VI 1 min.

(3) Extinction - Two lever-Lock out. In order to possibly facilitate production of contrast effects by one subject, responding was eliminated by changing to a mult VI 1 min EXT schedule during which responding was restricted by locking the operation of the right lever. This lever had previously been associated with the red stimulus condition and extinction.
RESULTS

Response rates during each session were computed separately for each ply of the multiple schedules. Figures 1, 2 and 3 show response rates for each subject throughout all phases of the experiment.

**Extinction - Single lever.** In the single lever mult VI VI condition, response rates were generally higher during presentations of the green stimulus. Response rates for both components, however, showed variations within stable ranges for each subject, although D.E. responded at roughly twice the rates of subjects D.C. and N.S.

When the schedule during the green stimulus condition was shifted to extinction, changes in responding occurred. Subjects N.S. and D.C. showed rate decreases during both plys following the change to extinction. Subject D.C. showed what may have been a transitory contrast effect during sessions 16-19, but this quickly disappeared.

Response rates for all subjects showed a general decrease during extinction components with smaller reductions in rate across VI components. Contrast effects of the type noted in previous research with infrahuman subjects were not observed.

Sequential contrast effects (Figures 4-6) were not present during the single lever condition. These effects occur during mult VI EXT when the mean rate in S⁺ (VI) components following S⁻ (EXT) components is typically higher than the rate in S⁺.
components following other S+ components. However, as is shown, these effects did not occur.

**Extinction - Double lever.** During the mult VI EXT portion of this condition both subjects N.S. and D.E. (Figures 1 and 2) showed steady increases in response rate in the VI component (positive contrast). Subject N.S.'s response rate during VI increased more than twice its VI rate during mult VI VI. Subject D.E. displayed a more gradual increase in the VI rate for the constant VI component than had prevailed during mult VI VI. The contrast effect produced in subject D.E. gradually dissipated with the response rate returning to the previous baseline level. For both of these subjects, response rate in the extinction component systematically decreased to very low levels so that almost complete extinction was obtained. In subject D.C.'s case, responding during extinction components was not significantly reduced and very little change in the VI response rate occurred. The drop in VI rate following session 35 coincided with the subject's return from a seven day illness. Re-establishment of the mult VI VI baseline conditions resulted in a return to the prior baseline levels for all subjects although recovery of responding during green for D.E. occurred slowly.

Sequential contrast effects (Figure 4) were shown only by N.S. during the double lever condition. Response rate during S+ (VI) components following S- (EXT) components was substantially higher than in S+ components following S+ components.
Since subjects D.E. and D.C. responded with higher rates during S+ components that followed other S+ components, sequential contrast was not observed.

Figures 7, 8 and 9 show sample cumulative response records obtained during the double lever condition. Comparisons between the curves can be made with respect to response rates during the green stimulus condition. Higher response rates occurred during the constant VI component (downward position of the event pen) when the schedule was mult VI EXT than when it was mult VI VI. Subjects N.S. and D.E. (Figures 8 and 9) show almost complete cessation of responding during extinction components whereas D.C. (Figure 9) shows little reduction in extinction responding.

**Extinction - Double lever-Lock out.** Changing the conditions from mult VI VI to mult VI EXT did not generate contrast effects in the response rates of D.C. To provide for greater differentiation between conditions the lock out procedure was attempted with a resulting increase in the VI rate (positive contrast) occurring soon after responding during red was eliminated (see Figure 3). With the addition of the lock out sequential effects (Figure 6) are also seen. Cumulative response record comparisons, readily display the presence of much higher rates of responding during the constant VI component with respect to the previous rates during mult VI VI and mult VI EXT.
DISCUSSION

The results of this study are in some ways consistent with previous multiple schedule studies of behavioral contrast. The positive contrast effects demonstrated during mult VI EXT (double lever) are similar to those reported by Reynolds (1961a).

During the single lever condition, however, positive contrast was not demonstrated by any subject. Positive contrast develops in the constant ply of a multiple schedule when some procedural variation is used to reduce response rate in a second ply. In several cases (Reynolds, 1961a, Terrace 1968, Reynolds and Limpo, 1968) contrast effects were observed when response rates during the varied ply were substantially reduced. This reduction was not observed for any subject during the single lever condition. For two subjects a negative induction effect occurred indicating poor stimulus control over responding in the presence of the two stimuli. To the extent that the subjects could not discriminate between the two schedules in the single lever conditions responding in extinction was facilitated.

The inability to obtain control over extinction responding in the single lever condition is also akin to other observations of extinction responding in human subjects (O'Brien, 1968, Weiner, 1964, 1970). In an unpublished study from our laboratory, response rates did not decrease during extinction in
mult VI EXT schedules. Subjects in this study were required to operate a toggle switch for points later exchangeable for tokens. Following experimental sessions, subjects frequently would discuss the different response "patterns" they had used to obtain points. This superstitious "testing" of the contingencies would indicate the presence of as yet unspecified variables which may have impeded the progress of extinction.

Much greater control over responding was observed when the procedure was modified to include two levers. In this condition the subjects were required to move from one side of the chamber to the other in order to respond. This change appeared to make the stimulus conditions during the double lever phase more discriminative as indicated by the almost immediate acquisition of stimulus control over extinction responding.

Following the change to mult VI EXT for two of the subjects, rapid development of positive contrast was demonstrated during the double lever condition. With the third subject, contrast was not produced despite the use of two levers. When responding was eliminated by the lock-out procedure during the varied ply, a similar contrast effect was observed in the constant VI ply.

Sequential contrast effects were also exhibited by subject N.S. during double-lever mult VI EXT and by D.C. during mult VI EXT with added lock-out. Response rates were generally higher in those VI components following extinction.
(components than in those VI components following other VI components. These data are consistent with the sequential effects reported by Terrace (1966a) and O'Brien (1968). In O'Brien's study sequential effects were most evident in early sessions and rapidly disappeared by later sessions. The presence of extinction responding in the O'Brien study may account for the transitory nature of the sequential contrast effects reported.

An unusual finding in the double lever mult VI EXT sequential data for subject D.C. is the increase in response rate during VI components following other VI components. Not having to change chamber positions for the VI following VI (VI/VI) case may be responsible for the increased rates. Lower rates in VI following EXT (VI/EXT) components may be accounted for by the change in seating location required by the multiple schedule. In the mult VI EXT with lock-out the subject could remain stationary since responding had been eliminated on one lever. In this context the subject exhibited higher rates in VI/EXT components than in VI/VI components--sequential contrast.

The results of this study indicate that behavioral contrast can be demonstrated with human subjects. In this regard the generality of the contrast effect has been extended. Additional study could well be directed to the further identification of variables which may be related to the development of behavioral interactions in human subjects in basic research as well as applied settings.)
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FIGURE 1

Response rate per minute for both plys of the multiple schedule during mult VI VI, mult VI EXT and mult VI VI for both single and double lever conditions for subject N.S.
FIGURE 2

Response rate per minute for both plys of the multiple schedule during mult VI VI, mult VI EXT and mult VI VI for both single and double lever conditions for subject D.E.
**Figure 3**

The graph shows the response rates per minute across sessions for different lever conditions. The horizontal axis represents the sessions, and the vertical axis represents the responses per minute. The graph includes data for both constant VI and manipulated VI conditions. The legend indicates the different conditions:

- **Constant VI** represented by solid dots.
- **Manipulated VI** represented by open circles.

The conditions are labeled along the graph, such as SINGLE LEVER (S.L.), DOUBLE LEVER (D.L.), and different variations of VI with and without EXT conditions.
FIGURE 5

Response rates per minute for both plys of the multiple schedule during mult VI VI, mult VI EXT, mult VI VI, and mult VI EXT with lock-out during both single and two lever conditions for subject D.C.
FIGURE 4
Sequential contrast effects. The rates of responding during S+ (VI) components which were preceded by S- (EXT) compared to rates during S+ components which were preceded by S+ for subject N.S.
Sequential contrast effects. The rates of responding during S+ (VI) components which were preceded by S- (EXT) compared to rates during S+ components which were preceded by S+ for subject D.E.
FIGURE 6

RESPONSES PER MINUTE

SINGLE LEVER S.L. DOUBLE LEVER D.L.
MULT VI-I MULT VI-I EXT MULT VI-I EXT MULT VI-I VI-I MULT VI-I LO

S+ S+
S- S-
SUBJECT DC

SESSIONS
Sequential contrast effects. The rates of responding during S+ (VI) components which were preceded by S- (EXT) compared to rates during S+ components which were preceded by S+ for subject D.C.
FIGURE 7

Representative cumulative response records obtained during A mult VI VI and B mult VI EXT during the double lever condition for subject N.S. Oblique pips on the curves indicate reinforcement delivery. The downward position of the event marker indicates the green stimulus condition (right lever), the upward position the red stimulus condition (left lever).
FIGURE 8

Representative cumulative response records obtained during A mult VI VI and B mult VI EXT during the double lever condition for subject D.E. Oblique pips on the curves indicate reinforcement delivery. The downward position of the event marker indicates the green stimulus condition (right lever), the upward position the red stimulus condition (left lever).
FIGURE 9

Representative cumulative response records obtained during A mult VI VI and B mult VI EXT during the double lever condition for subjects D.C. Oblique pips on the curves indicate reinforcement delivery. The downward position of the event marker indicates the green stimulus condition (right lever), the upward position the red stimulus condition (left lever).

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FIGURE 10

Representative cumulative response records obtained during A mult VI VI and B mult VI EXT during the double lever condition with lever lock-out for subject D.C. Oblique pips on the curves indicate reinforcement delivery. The downward position of the event marker indicates the green stimulus condition (right lever), and upward position the red stimulus condition (left lever).