

Interaction effects in a multiple schedule of signaled and unsignaled reinforcement

ROBERT W. POWELL and LINDA J. PALM
University of South Florida, Tampa, Florida 33620

Pigeons received baseline training on an equal-valued multiple unsignaled variable-interval/signaled variable-interval schedule. This procedure resulted in high and low response rates during the unsignaled and signaled components, respectively. Behavior during each component was then separately extinguished. Extinction of the unsignaled component resulted in positive contrast in the signaled variable-interval component. When reinforcement was withheld during the signaled component, marked increases in responding during this component occurred, and responding in the presence of the signal was very resistant to extinction. Accompanying the breakdown of the discrimination during the signaled component was an increase in the rate of responding in the unsignaled variable-interval component (i.e., positive induction). The implications of these results for several theories of behavioral contrast are considered.

When one component of a multiple schedule of reinforcement is manipulated while the other component remains constant, changes in response rates often occur during both components. These are called interaction effects, and they may take either of two forms. When the response rates in both components show increases or decreases in the same direction, the interaction effect is termed positive or negative induction, respectively. When the changes in response rate are in opposite directions, the effect is called contrast. Positive contrast is defined by an increase in rate during the unchanged component, while the rate during the changed component decreases. Alternatively, negative contrast refers to decreases in responding during the unchanged component accompanied by increases in responding during the changed component.

Of the two types of interaction, contrast has attracted the most attention from theoreticians. One of the earliest theories (Reynolds, 1961) suggested that the response rate in the constant component of a multiple schedule is inversely related to the reinforcement frequency in the variable component. Reynolds found that when a multiple variable-interval/variable-interval (mult VI-VI) schedule was changed to a mult VI extinction (EXT) schedule, an increase in the rate of responding during the unchanged VI component occurred as responding declined in the EXT component. The change from a mult VI-VI to a multiple VI-differential reinforcement of other behavior (mult VI-DRO) schedule, however, did not result in contrast. On the basis of these findings, Reynolds proposed that contrast is a function of the relative frequency of reinforcement in the two components. Decreasing the reinforcement rate in the

variable component produces an increase in the relative frequency of reinforcement in the constant component.

A second theory has been proposed by Terrace (1966, 1968). In his studies, Terrace has employed procedures to hold reinforcement frequency constant in the variable component of a multiple schedule while reducing response rate in that component by a change to a different schedule. In one study (Terrace, 1968), pigeons were trained to respond on a VI 1-min schedule and then were changed to a mult VI/differential reinforcement of low rate (DRL) schedule. The DRL schedule was adjusted to insure approximately equal rates of reinforcement in two components. Although three of the subjects showed little change in the VI rate, for the remaining three subjects, the DRL schedule produced a decrease in response rate during this component, accompanied by an increase in response rate during the VI component. Similar experiments by Weisman (1969, 1970) using mult VI-DRO and mult VI-DRL schedules have also reported positive contrast effects. Powell (1971) also found positive contrast when employing a procedure that did not involve changes in the relative frequencies of reinforcement in the components of a multiple schedule. In this experiment pigeons were trained under mult VI-EXT or variable-ratio (VR)-EXT schedules until discriminative performance was nearly perfect. The subsequent introduction of a fixed-ratio (FR) schedule of electric shock punishment during the VI or VR reinforcement components reduced responding in these components. Accompanying this change was an increase in responding during the unpunished extinction component. On the basis of the above findings, it has been suggested that a reduction in reinforcement frequency is not a necessary condition for the production of behavioral contrast; rather, a reduction in the rate of responding to one of the discriminative

Reprints may be obtained from Robert W. Powell, Department of Psychology, University of South Florida, Tampa, Florida 33620

stimuli of a multiple schedule is a sufficient condition. Terrace (1966) has further proposed that contrast effects may have an emotional origin.

A third approach to contrast has been termed additivity theory by Gamzu and Schwartz (1973) and has been advocated in a similar version by Rachlin (1973). Recent research on autoshaping has indicated that responding in certain operant conditioning situations may be engendered by stimulus-reinforcer dependencies as well as by the conventionally studied response-reinforcer dependencies. Gamzu and Schwartz have noted that since both types of relationships are present in discrimination training with multiple schedules, they might have a "mutually enhancing effect" (1973, p. 71) that could result in interaction effects. For example, in an equal-valued mult VI-VI schedule correlated with different discriminative stimuli, the response-reinforcer contingency controls keypecking in pigeons, and the rates of responding in the two components are comparable. With the change to mult VI-EXT, responding in the EXT component declines while responding in the constant component increases. The important difference, according to Gamzu and Schwartz, is that the constant component now contains a differential stimulus-reinforcer dependency, which via an autoshaping process would generate pecking in the absence of a response-reinforcer contingency.

In our research we have been particularly concerned with the effects of deprivation and extinction upon responding under different levels of discriminative control. It has been suggested that strong discriminative control results in contrast, whereas weak discriminative control leads to induction (Pear & Wilkie, 1971). However, in a study in which strong discriminative control was established via errorless discrimination training, no interaction effects were observed (Terrace, 1966). In one experiment (Powell, 1973), discriminative responding in pigeons was studied under mult VI-EXT schedules in which the components were correlated with either visual or auditory stimuli. The use of visual cues resulted in a high degree of discriminative control, with a high rate of responding during the VI stimulus and a near-zero level of responding in the presence of the EXT stimulus. Discriminative responding was much less accurate when tones were employed. When reinforcement was subsequently withheld during the VI component, there was no interaction between components when discriminative control was strong as responding under the VI schedule decreased. However, when discriminative control was weak as responding decreased in the presence of the VI stimulus, responding decreased markedly during the EXT stimulus, constituting negative induction. Further, when positive reinforcement was reinstated, responding increased in the presence of both the VI and EXT stimuli (i.e., positive induction).

Recently, we have utilized a procedure that produces large differences in response rates under two multiple-schedule components with the same frequencies of rein-

forcement, employing visual cues only. This procedure was developed by Brownstein and his associates, who added a distinct stimulus to one component of an equal-valued multiple schedule to signal the availability of a reinforcer. In these studies, responding in pigeons was first maintained on either a mult fixed-interval (FI-FI) schedule (Brownstein & Newsom, 1970) or a mult VI-VI schedule (Brownstein & Hughes, 1970), and then one component was changed from unsignaled (Unsig) to signaled (Sig) reinforcement. In each type rate of responding decreased in the Sig component, but the rate of responding in the Unsig component increased (positive contrast). When the signal was removed, negative contrast occurred.

In our most recent study (Powell & Palm, 1977), pigeons first received baseline training on an equal-valued Unsig-VI/Sig-VI schedule. During the Unsig component, the key-light color remained constant; under the Sig component, the key light changed color whenever a reinforcer became available for responding. The procedure resulted in high and low response rates during the Unsig and Sig components, respectively. We then found that increases in deprivation produced by systematic changes in body weight resulted in differential effects under the two components, with response rate increasing during the Unsig component but showing little or no change under the Sig component.

This experiment was undertaken to extend our analysis of behavior occurring at substantially different response rates under two components of a multiple schedule, by separately extinguishing behavior under each component. We anticipated that changes in response rates, in the form of interaction effects, might occur that would provide differential support for one of the three theories of behavioral contrast described earlier. Our previous findings suggested that responding under the Sig component would be less affected by extinction than responding under the Unsig component.

METHOD

Subjects

Five adult homing pigeons and one adult White Carneaux pigeon, all with extensive experimental histories, were used. Subjects were maintained at approximately 85% of their free-feeding weights.

Apparatus

The experimental apparatus was a standard pigeon test chamber (Lehigh Valley Model 1519C) 15.5 x 15.4 x 132 cm, containing two translucent response keys. One key remained dark and inoperative. The other key, located on the right side of the front panel, was illuminated by green, red, or white lights (7 W, 28 V dc) and was operated by a minimum force of 15 g. The reinforcer was 2-sec access to Purina Pigeon Checkers.

Procedure

Subjects were first reinforced in the presence of different visual stimuli on a two-ply multiple schedule with identical VI 1-min schedules associated with each component. The Unsig component was correlated with a green key light, whereas during the Sig component a red key light was changed to white

to signal the availability of a reinforcer for responding. Thus red was correlated with extinction and white was correlated with a schedule of continuous reinforcement. The components, which were of 10 min duration, alternated successively. The initial component in a session changed from day to day. Experimental sessions were 40 min/day, with two presentations of each component of the multiple schedule. The stability criterion was defined by variation in response rates within $\pm 15\%$ of the mean rate over five consecutive sessions.

Following the baseline phase, all reinforcement was withheld in one component while the other component was unchanged. Behavior was studied as responding was extinguished separately under the Unsig-VI component, the Sig-VI component, and finally under both components simultaneously. During extinction of the Unsig component, the green key light was turned off for 2 sec at the scheduled reinforcement intervals, but the food hopper was not presented. Similarly, during Sig-EXT, the response key was darkened for 2 sec at scheduled intervals, but the hopper was not operated. Each extinction procedure continued until responding within the EXT component was stable over five consecutive sessions or until 20 sessions had been completed. Subjects were returned to the mult Sig-VI 1-min/Unsig-VI 1-min schedule until performance stabilized following each extinction phase.

RESULTS

Baseline Training

The sig-VI/Unsig-VI procedure resulted in consistently high rates of response during the Unsig component and a very low response rate during the Sig component. Under the latter condition, the subjects rarely responded except when a reinforcer was available, so their response rates approximated 1.0 responses/min.

Extinction Phases

Figure 1 shows the normalized response rates for all subjects under each schedule component during the three extinction phases. The normalized rates were determined by dividing the response rate for each component by the preceding baseline response rate for that component.

Extinction during Unsig-VI. The change from mult Sig-VI/Unsig-VI to mult Sig-VI/Unsig-EXT resulted in a large decrease in responding during the Unsig component for all birds. For two subjects (P-19, P-24), this decrease was accompanied by little or no change in response rate during the Sig-VI component. The remaining four subjects, however, showed positive contrast. That is, as responding decreased in the EXT component, increases above baseline occurred in the unchanged, Sig-VI component; in other words, the birds began to respond during the red key light.

Extinction during Sig-VI. The results obtained when reinforcement was not presented during the Sig-VI component were more surprising. This phase was characterized by severe disruptions of the red-white discrimination, and five of the birds began to respond at much higher rates in the presence of the red stimulus. Although two of these five birds eventually showed a decrease in response rate below the baseline level during the Sig component (P-2, P-23), extinction of responding was not as complete as that demonstrated during the Unsig-EXT component. While response rates in the Sig component varied markedly between sessions, rates during the Unsig

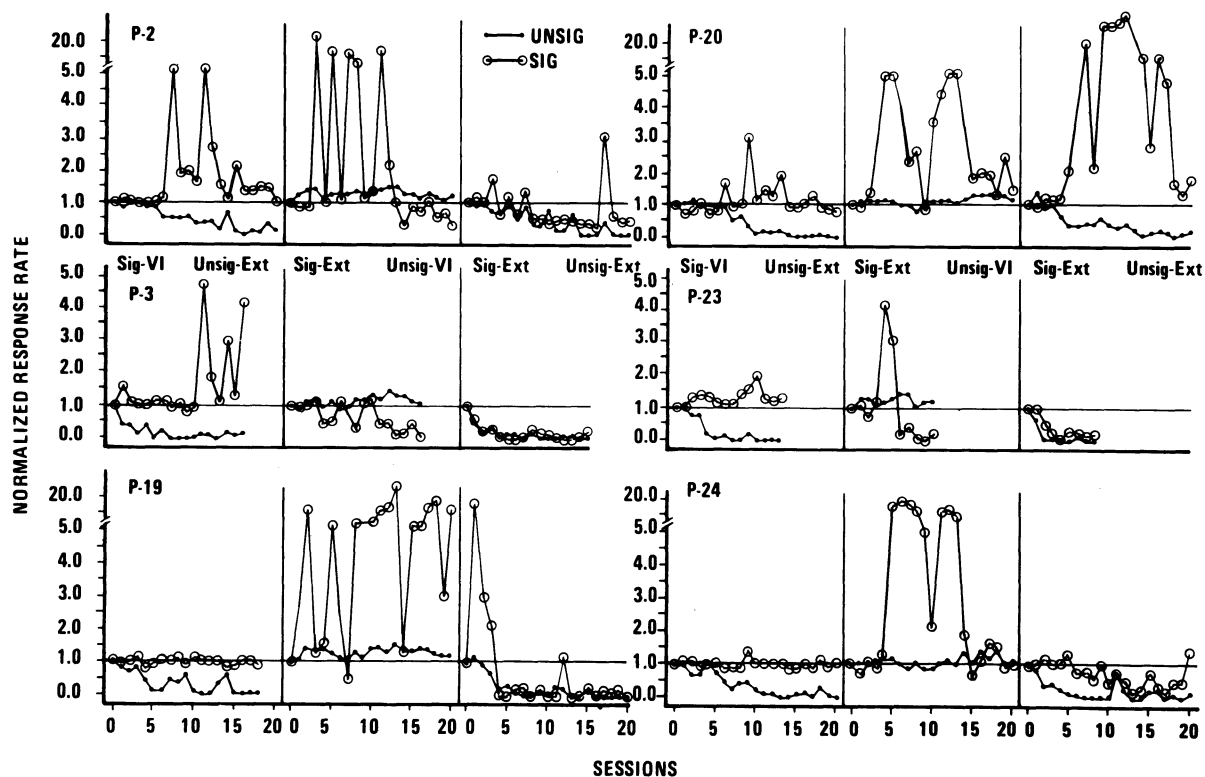


Figure 1. Normalized response rates under the Sig and Unsig components of the multiple schedule during each extinction phase. The sessions labeled "0" represent the preceding mult VI-VI baseline in rates.

component were more consistent. All subjects except P-24 showed slight increases in response rates during the Unsig component. Thus, with the exception of P-3 and P-24, four birds showed positive induction during this extinction phase.

Extinction during both components. This procedure typically produced a gradual reduction in responding during the Unsig component for all subjects. Two birds (P-3, P-23) showed a rapid and almost complete cessation of responding under both components of the schedule. P-19 also displayed nearly complete extinction of responding under both components by the end of this phase, although there was an increase in responding during the first three sessions under the Sig component. The remaining three birds also showed varying degrees of rate increases during the Sig component.

DISCUSSION

The results of this experiment showed that extinction of the Unsig-VI component results in positive contrast in the Sig-VI component. When reinforcement was withheld during the Sig component, this not only produced a breakdown of the red-white discrimination but elevated responding in the unsignaled component as well. These findings fail to support our expectation that the low response rate controlled by the Sig reinforcement schedule would be less affected by the extinction procedure than the high rate controlled by the Unsig schedule. Additionally, these results are not completely consonant with any of the three theories of contrast discussed earlier. The relative frequency of reinforcement theory would predict positive contrast whenever reinforcement is withheld during one of the multiple-schedule components but is presented normally in the other component. Clearly, this did not occur when Sig reinforcement was replaced by extinction.

The response suppression view also predicts the results of the Unsig-EXT phase, but it fails to account for our positive induction findings. According to the response-suppression position, when the Unsig-VI component is changed to extinction, as the high rate of responding in this component is reduced, positive contrast should occur. However, there should be no interaction during extinction under Sig reinforcement, since response rate is very low under this condition prior to extinction.

As noted above, additivity theory predicts that contrast may occur whenever the discriminative stimuli of a multiple schedule are correlated with different conditions of reinforcement. Applied to our procedure, this suggests that contrast should result when either the Sig-VI or the Unsig-VI component is changed to extinction. However, our baseline schedule contained a differential stimulus-reinforcer dependency prior to the change to extinction. That is, in the Sig component the signal is perfectly correlated with reinforcement, and the red key light is perfectly correlated with nonreinforcement. In the unsignaled component, the relationship between key-light color and reinforcement is not precise. Thus as subjects begin to learn the red-white discrimination during baseline training, from additivity theory one might expect to see at least a temporary elevation of responding in the Unsig-VI component. Examination of the subjects' records indicated a very rapid decrease in response rate during the Sig component; by the end of the fourth session, subjects were responding almost exclusively to the white key light. Additionally, no evidence of an elevation in the Unsig-VI rate was found when response rates in the Sig-VI component were changing or after they had stabilized.

An alternative approach to these results is suggested by Terrace's (1966) discussion of errorless discrimination learning.

He reported that when a discrimination between a stimulus perfectly correlated with reinforcement (S+) and a stimulus perfectly correlated with extinction (S-) is learned without errors, an abrupt change from reinforcement to extinction in the presence of S+ results in a disruption of the discrimination with many responses occurring in the presence of S-. If the probability of reinforcement in S+ is progressively reduced, however, discriminative performance is not disrupted. These findings have led Terrace to conclude that errorless training may produce a "lack of frustration tolerance" (1966, p.335). Although we have not employed an errorless training procedure during the Sig component of the baseline schedule, by the end of this period the subjects do show virtually errorless performance. That is, almost 100% of their responses during the Sig component occur in the presence of the signal. Since under our procedure, subjects are reinforced for each response in the presence of the white stimulus and only intermittently during the green stimulus, it follows from Terrace that the change from Sig-VI to extinction constitutes a more aversive event than the change from Unsig-VI to extinction. The motivational consequences of this "frustration effect" might be sufficiently strong not only to disrupt the red-white discrimination, but also to carry over into the Unsig-VI component, resulting in positive induction. This is what we observed.

REFERENCES

- BROWNSTEIN, A. J., & HUGHES, R. G. The role of response suppression in behavior contrast: Signaled reinforcement. *Psychonomic Science*, 1970, **18**, 50-52.
- BROWNSTEIN, A. J., & NEWSOM, C. Behavioral contrast in multiple schedules with equal reinforcement rates. *Psychonomic Science*, 1970, **18**, 25-26.
- GAMZU, E., & SCHWARTZ, B. The maintenance of key pecking by stimulus contingent and response-independent food presentations. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- PEAR, J. J., & WILKIE, D. M. Contrast and induction in rats on multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 289-296.
- POWELL, R. W. Some effects of punishment shock intensity upon discriminative responding. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 109-116.
- POWELL, R. W. Effects of stimulus control and deprivation upon discriminative responding. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 351-360.
- POWELL, R. W., & PALM, L. Further evidence of interaction between deprivation effects and stimulus control of responding: III. *Bulletin of the Psychonomic Society*, 1977, **9**, 307-310.
- RACHLIN, H. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- REYNOLDS, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 57-71.
- TERRACE, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.
- TERRACE, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 727-741.
- WEISMAN, R. G. Some determinants of inhibitory stimulus control. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 443-450.
- WEISMAN, R. G. Factors influencing inhibitory stimulus control: Differential reinforcement of other behavior during discrimination training. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 87-91.