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Schedule interactions and stimulus control

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AN ABSTRACT OF THE THESIS OF Andrew Louis Homer for the
Master of Science in Psychology presented August 27, 1971.

Title: Schedule Interactions and Stimulus Control.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

Robert E. Jones, Jr., Chairman

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Four types of schedule interactions have been defined: positive contrast, negative contrast, positive induction, and negative induction. Most work has centered on the necessary conditions for positive contrast. One position states that a reduction in reinforcement frequency is necessary; the other view states that a reduction in response rate is necessary. Neither view can account for the occurrence of induction. The present experiment tests the hypothesis that stimulus control effects the occurrence of either contrast or induction. Three pigeons were trained to respond for primary reinforcement (strong stimulus control condition), and three pigeons were trained to respond for conditioned reinforcement (weak stimulus control condition). A response rate decrease was caused by changing the schedule of reinforcement from MULT EXT, VI 1-min, EXT, VI 1-min to MULT VI 1-min, VI 1-min, VI 1-min, VI 1-min for primary reinforcement birds, and to MULT (CHAIN

VI 1-min, VI 1-min), (CHAIN VI 1-min, VI 1-min) for conditioned reinforcement birds. Negative contrast was observed for all birds receiving primary reinforcement, but positive induction occurred for two of three birds receiving conditioned reinforcement. In the next phase a response rate decrease was caused by changing the schedule to MULT VI 1-min, VI 1-min, DRO 20-sec, VI 1-min for primary reinforcement birds, and to MULT (CHAIN VI 1-min, VI 1-min), (CHAIN DRO 20-sec, VI 1-min) for conditioned reinforcement birds. Two of the primary reinforcement birds showed positive contrast, while the third showed negative induction. Two of the conditioned reinforcement birds showed negative induction, while the third showed no effect. Gradients of stimulus control showed no difference between the groups due to the prolonged training before testing for stimulus control. It was concluded that differential amounts of stimulus control can account for the differences in the schedule interactions in this experiment and those observed in previous research.

SCHEDULE INTERACTIONS

AND

STIMULUS CONTROL

by

ANDREW LOUIS HOMER

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INTRODUCTION

A change in the schedule of reinforcement in one component of a multiple schedule produces a response rate change in the other component. Reynolds (1961a) called this an interaction. He defined four types of interactions: positive contrast, negative contrast, positive induction, and negative induction. The interaction was positive if the response rate increased from the prevailing rate in the component in which the schedule change did not occur, and negative if response rate decreased. If the changes in rates in the two components were in the opposite direction the interaction was called contrast. If the changes were both in the same direction the interaction was called induction. In positive induction the rates in both components increase; in negative induction they decrease. In positive contrast rates diverge; in negative contrast the rates converge.

Later research investigated the necessary and sufficient conditions for the production of positive contrast. Two positions have been proposed. The first hypothesis was proposed by Reynolds (1961b). He stated that positive contrast resulted from a decrease in the relative rate of reinforcement. He changed a MULT VI 3-min, VI 3-min to MULT VI 3-min, EXT,¹ and reliably produced positive contrast. To separate the effects of reduction in response rate from reduction in reinforcement rate, he reinforced pigeons for not responding for 50 sec. In

¹For a thorough description and definition of schedules of reinforcement and combinations of schedules see Ferster and Skinner (1957).

this change from MULT VI 3-min, VI 3-min to MULT VI 3-min, DRO 50-sec (differential reinforcement of other behavior) positive contrast did not occur. While both the DRO and EXT contingencies produced a reduction in response rate, positive contrast occurred only when EXT was used. He concluded that a reduction in the frequency of reinforcement is a necessary condition for positive contrast to occur. Nevin (1968) produced similar results. He compared DRO schedules in which the durations were based on either a VI .33-min, VI 1-min, or VI 3-min schedule. He also used EXT to produce a reduction in rate. His data showed that in the two shorter DRO schedules, negative induction and no inhibitory stimulus control developed. In the long DRO and in the EXT schedules positive contrast and some inhibitory control occurred. He also concluded that a reduction in reinforcement frequency was a necessary condition for positive contrast.

Mariner and Thomas (1969) manipulated amount of reinforcement instead of frequency of reinforcement. A MULT VI 1-min, VI 1-min schedule with a 6-sec access to grain in each component, was changed to a MULT VI 1-min, VI 1-min schedule with a 6-sec and 2-sec access to grain. In addition, for half the pigeons the different feeding durations were signaled by changing the illumination of the grain hopper. This was done so that the different durations were immediately discriminable. They observed positive contrast for pigeons receiving the signaled feeding duration, but negative induction occurred for three of four non-signaled pigeons. They concluded that manipulation of amount of reinforcement, if signaled, functions like a reduction in frequency of reinforcement. Gay and Wilton (1969) reported similar results mani-

pulating amount. In another experiment they reported (Wilton & Gay, 1969) that a change from a VI 1-min schedule to a CHAIN VI 1-min, VI 1-min resulted in a rate increase in the terminal VI 1-min schedule which they labeled positive contrast. They concluded that conditioned reinforcement is similar to a decrease in amount of reinforcement and leads to positive contrast.

An alternative to the reduction in reinforcement hypothesis was proposed by Terrace (1968). He stated that a stimulus becomes functionally negative by a reduction in rate of responding and this was a necessary condition for positive contrast. A reduction in reinforcement frequency usually produces a reduction in response rate, but it need not. In Terrace's (1963) errorless procedure a discrimination was trained without a reduction in rate and did not produce positive contrast. Terrace (1968) reported three experiments in support of his hypothesis. In the first, a MULT VI 5-min, VI 5-min schedule was changed to MULT VI 5-min, VI 1-min. This resulted in positive induction. He compared this to a MULT VI 1-min, VI 1-min schedule which was changed to MULT VI 5-min, VI 1-min. This resulted in a decrease in response rate in the VI 5-min schedule and positive contrast. In another experiment a baseline was established for a MULT VI 1-min, VI 1-min schedule. Contingent electric shock was then introduced in one component. This resulted in a decrease in response rate while rate of reinforcement was held constant, and positive contrast occurred. In the third experiment a MULT VI 1-min, VI 1-min schedule was changed to MULT VI 1-min, DRL 6-sec (differential reinforcement of low rates; the first response after 6 sec produced reinforcement). This also resulted in a

decrease in response rate and positive contrast. Other investigators (Reynolds & Limpo, 1968; Weisman, 1969) have reported the same result with DRL schedules.

Weisman (1970) obtained positive contrast and inhibitory stimulus control in a DRO schedule that maintained equal reinforcement frequency in both components of the multiple schedule.

A reduction in response rate is necessary to produce positive contrast, but not all procedures that reduce response rate result in positive contrast. Both the reduction in response rate and the reduction in reinforcement hypotheses are supported by data, but neither view deals with the occurrence of induction. Recently, Pear and Wilkie (1971) proposed but did not test the hypothesis that induction results when a condition of weak stimulus control exists, whereas contrast occurs when strong stimulus control exists. The present experiment tested this hypothesis.

Early in a chain schedule a condition of weak stimulus control exists, but after prolonged exposure to a chain, stimulus control develops (Switalski & Thomas, 1967). Wilton and Gay (1969) reported that a change from VI 1-min to CHAIN VI 1-min, VI 1-min produced a rate increase in both components of the chain. They called this an instance of positive contrast because no baseline for response rate in the first component was obtained. This interaction is more like positive induction.

In the present experiment, the amount of stimulus control was manipulated by maintaining responding with primary reinforcement in multiple schedules or conditioned reinforcement in chain schedules. To

set the occasion for the occurrence of either contrast or induction, an increase in response rate was obtained by changing component schedules for both groups from EXT to VI 1-min, and response rate decreases were obtained by changing a component schedule from VI 1-min to DRO 20-sec. The schedule interactions that occurred as a result of these changes were compared for both groups. Gradients of stimulus control were obtained at the conclusion of the experiment.

METHOD

I. SUBJECTS

Six adult male King pigeons, obtained from a local supplier, were maintained at 80% of their free-feeding weight throughout the experiment.

II. APPARATUS

A two-key pigeon chamber, 34 by 28 by 28 cm, was located in a modified picnic chest (Ferster & Skinner, 1957). The 2.5 cm response keys were centered 23 cm from the floor and 12.5 cm apart, on a metal panel separating the pigeon's chamber from the area containing the stimulus and food presentation mechanism. The response key on the right was covered throughout the experiment by a metal plate of the same material as the panel. The experimental chamber was diffusely lighted from above by a 15 w light bulb. An opening 5 by 5 cm centered in the front panel 7.6 cm from the floor provided access to a solenoid-operated grain hopper. A white noise generator and a blower operated during the experiment to mask extraneous sounds and regulate the temperature in the chamber. A 12.6 by 7.6 cm one-way mirror was located in the rear wall of the chamber to permit observation of the pigeon's behavior. The response key was transilluminated by a multiple stimulus projection device, enabling automatic control of the stimulus presentation during both training and testing. All line stimuli were 2 by 25 mm black lines centered on the white key. The schedule

intervals were generated by a progression proposed by Fletcher and Hoffman (1962), and consisted of 31, 31 30, and 29 intervals for the four VI 1-min schedules. Conventional electro-mechanical scheduling and recording equipment was located in an adjacent room.

III. PROCEDURE

Table I presents the procedures that were used in this experiment. The three phases of the experiment are shown at the left of the table. The left section shows the schedules and stimuli for the pigeons that received conditioned reinforcement; the right section shows the schedules and stimuli for pigeons that received primary reinforcement. In each phase the stimuli and component schedules were identical.

Shaping and continuous reinforcement (CRF) took place in the presence of the white key, following procedures similar to those outlined by Ferster and Skinner (1957). In Phase I all birds were exposed to MULT EXT, VI 1-min, EXT, VI 1-min. The birds were assigned to the experimental conditions on the basis of matched response rates in the VI 1-min components of this phase. Birds KP-826, KG-439, and KP-829 were assigned to the primary reinforcement condition; birds KP-743, KP-820, and NB were assigned to the conditioned reinforcement condition. In Phase II a rate increase in the vertical and horizontal line stimulus components was programmed by changing the schedule to MULT VI 1-min, VI 1-min, VI 1-min, VI 1-min for birds receiving primary reinforcement and to MULT (CHAIN VI 1-min, VI 1-min), (CHAIN VI 1-min, VI 1-min) for birds receiving conditioned reinforcement. In Phase II a DRO 20-sec

schedule was introduced during the horizontal line stimulus period to produce a rate decrease. After responding had stabilized, testing for stimulus control of line orientation occurred.

All animals were run daily throughout the experiment. In each daily session the stimuli appeared in fixed order: vertical line, white light, horizontal line, white light. This cycle was repeated eight times in a session. Each stimulus period ended when the reinforcement requirement was met. The EXT periods in Phase I ended when a VI 1-min time period elapsed. All transitions between phases occurred in the middle of a daily session.

A warm-up period of four cycles of the Phase III schedule preceded testing for stimulus control. In testing, lines of 0° , 22° , 45° , 67° , 90° , 112° , 135° , 157° , and 180° orientation and the white light were presented in twelve blocks. Each block contained the ten stimuli in random order. Each stimulus was presented for 30 sec followed by a 10-sec time-out. No reinforcement was available during testing for stimulus control.

TABLE I

Sequence of experimental conditions

PHASE	CONDITIONED REINFORCEMENT CONDITION					PRIMARY REINFORCEMENT CONDITION				
	VERT. LINE	WHITE LIGHT	TO	HORIZ. LINE	WHITE LIGHT	VERT. LINE	WHITE LIGHT	TO	HORIZ. LINE	WHITE LIGHT
I	EXT	Shaping CRF VI 1		EXT	VI 1	EXT	Shaping CRF VI 1		EXT	VI 1
II	VI 1	→ VI 1		VI 1	→ VI 1	VI 1	VI 1		VI 1	VI 1
III	VI 1	→ VI 1		DRO 20- SEC	→ VI 1	VI 1	VI 1		DRO 20- SEC	VI 1

Testing for Stimulus Control

RESULTS

All birds except KG-439 had near zero rates of responding during the EXT components of the Phase I schedule. For this reason, KG-439 was assigned to the primary reinforcement condition.

I. PHASE I TO PHASE II

Figure 1a shows the results of the change from the Phase I schedules to the Phase II schedules for birds receiving primary reinforcement.

All birds showed negative behavioral contrast in the white key stimulus periods. Response rates in the vertical and horizontal line stimulus periods increased until responding in these periods reached the level of responding in the white key stimulus periods. At this point response rates in all stimulus periods increased for KG-439 and KP-829 until pre-contrast levels were met. The pre-contrast level was not recovered for KP-826; when the response rates converged this bird showed only a slight increase in rate.

Figure 1b shows the data for birds receiving conditioned reinforcement for responding in the presence of the vertical and horizontal line. In this case the data are not as consistent as those of the birds receiving primary reinforcement. Induction rather than contrast occurred for two of these birds. Bird KP-743 showed large positive induction in the white key stimulus periods. Bird KP-820 also showed positive induction. For this bird when rates in the vertical and horizontal line periods reached the Phase I level of the white key

Figure 1a. Individual response rates during the change from Phase I to Phase II for primary reinforcement birds.

Figure 1b. Individual response rates during the change from Phase I to Phase II for conditioned reinforcement birds.

periods, the induction rates declined so that rates were about equal in all four stimulus periods. Bird NB showed large induction in the half session after the schedule change but then rapidly declined and showed negative behavioral contrast effects. This bird had shown a similar rate decrease during Phase I.

Observations of the bird's behavior at this time showed that pecking continued at a high rate during this period but the reduction in rate was due to a shift of a large number of the pecks to the left of the response key. While no observations were made during the transition from Phase I to Phase II, it is possible that similar behavior caused the difference between this bird and the others in this condition.

Normalized response rates were entered into a 2 by 5 analysis of variance. The first factor was the reinforcement condition, and the second factor was daily sessions. The analysis showed statistically significant differences between the reinforcement conditions. $F(1,4) = 5.01$, $p < .10$.

II. PHASE II TO PHASE III

In this schedule change, a DRO 20-sec schedule was instituted in the presence of the horizontal line. During the DRO 20-sec schedule, pigeons that received primary reinforcement and those that received conditioned reinforcement developed superstitious behavior.

Figure 2a shows the results for birds receiving primary reinforcement.

Figure 2a. Individual response rates during the change from Phase II to Phase III for primary reinforcement birds.

Only KP-829 showed pronounced positive behavioral contrast. This occurred in all three of the other stimulus periods. The level of responding declined to base levels. Bird KP-826 showed a slight rate increase in the other three stimulus periods after four days' exposure to the DRO contingency. This did not decline to base level. Bird KG-439 showed negative induction effects in the three stimulus periods and this effect was most apparent in the presence of the vertical line.

Figure 2b shows the results for birds receiving conditioned reinforcement. All the birds receiving conditioned reinforcement showed similar differential effects between stimulus periods. Bird KP-743 showed induction in the vertical line stimulus period and in the white key stimulus that followed the DRO 20-sec period. By two days rates had returned to base line. Bird NB showed induction in the vertical line period and both white key stimulus periods. The rates in the presence of the white stimulus recovered to show positive contrast. Bird KP-820 showed no rate changes in the presence of the white key, but did show positive contrast in the presence of the vertical line. This level of responding increased to a higher level than that of the stimulus periods that resulted in primary reinforcement. The analysis of variance for this schedule change showed that the groups were not significantly different. $F(2,k) < 1$.

III. GRADIENTS OF STIMULUS CONTROL

Individual and group gradients of stimulus control are shown in Figure 3. The plot of response rates shows that about a third more total responding occurred to the line orientations among birds trained

Figure 2b. Individual response rates during the change from Phase II to Phase III for conditioned reinforcement birds.

Figure 3. Gradients of stimulus control. Primary reinforcement birds at left, conditioned reinforcement birds at right. Response rates during base period are at left of each graph.

with primary reinforcement. Total responses to line orientation for primary reinforcement birds was 3073 vs. 2030 for conditioned reinforcement birds. $t(4) = 1.094$, $p > .05$. To adjust for the difference between the birds' rates in the presence of line orientation, per cent of total responses to line orientation was plotted. These graphs show that the gradients are similar for both conditions. Birds trained with conditioned reinforcement showed slightly flatter gradients at the peak than primary reinforcement birds. All gradients appear to be symmetrical and similarly shaped except for bird KG-439, which showed plateaus on each side of the peak. Response rates during the test for stimulus control were entered into a 2 by 8 analysis of variance. The first factor was reinforcement condition and the second factor was line orientation. The interaction was not significant, indicating that reinforcement condition did not affect responding to the different stimuli. $F(7,28) < 1$. Both groups did respond significantly differently to the line orientations. $F(7,28) = 22.05$, $p < .01$.

DISCUSSION

The data presented support the hypothesis that stimulus control effects schedule interaction. When the response rate increases for any reason in one component of a schedule, one of three events can occur in the other component. The response rate may increase (positive induction), it may decrease (negative contrast), or it may remain unchanged (no interaction). Similarly, when the response rate decreases for any reason in one component of a schedule, one of three events may occur in the other. The response rate may decrease (negative induction), it may increase (positive contrast), or it may remain unchanged (no interaction). When a response rate reduction occurs, a condition of high stimulus control will produce positive contrast, while a condition of low stimulus control will produce negative induction. When an increase in response rate occurs, a condition of high stimulus control will produce negative contrast, while a condition of low stimulus control will produce positive induction.

When the chain schedule was introduced in Phase II, a condition of weak stimulus control existed (Switalski & Thomas, 1967) and positive induction resulted. For the birds that received primary reinforcement, negative contrast resulted.

The transition to the DRO contingency in Phase III produced inconsistent results. Two of the birds receiving conditioned reinforcement showed some negative induction effects; the third showed no interaction. Similarly, two of the birds that received primary reinforcement

ment showed positive contrast, while the third showed negative induction. This bird, KP-439, showed a relatively flatter gradient of stimulus control, indicating less stimulus control.

The lack of unambiguous results in Phase III may have been due to the development of stimulus control in the chain schedules. Switalski and Thomas (1967) showed that after twenty days' exposure to a chain, strong stimulus control existed. The gradients obtained in this experiment after thirty days' exposure to the chain schedule showed no differences between the birds receiving primary and conditioned reinforcement.

Research by Nevin (1968) and Weisman (1970) provides the best example of application of this hypothesis to previously obtained data. Both used DRO schedules and obtained gradients of inhibitory stimulus control. Nevin reported negative induction and no stimulus control in two short DRO schedules, but obtained positive contrast and some stimulus control in the longer DRO schedule and EXT. Weisman obtained positive contrast and stimulus control using a DRO schedule.

Mariner and Thomas (1969) obtained positive contrast in the signaled group and negative induction in the unsignaled group. The signal made the different feeding cycle durations immediately discriminable. The addition of stimuli also increases stimulus control (Fink & Patton, 1953; Butter, 1963).

Terrace obtained contrast in a change from MULT VI 1-min, VI 1-min to MULT VI 1-min, VI 5-min, but obtained induction in a change from MULT VI 5-min, VI 5-min to MULT VI 5-min, VI 1-min. Stimulus control is stronger in shorter VI schedules (Haber & Kalish, 1963; Hearst,

Koresko & Poppen, 1964).

While further research is necessary, the hypothesis accounts for the data in the present experiment as well as past experiments.

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