CONCEPT LEARNING AND VERBAL CONTROL UNDER PARTIAL REINFORCEMENT AND SUBSEQUENT REVERSAL OR NONREVERSAL SHIFTS

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Concept learning was studied with partial or continuous reinforcement, reversal or nonreversal shift, and reinforcement for placement or reason. Ss placed cards right or left and gave trial-by-trial reasons; half were reinforced for placements, half for reasons. In acquisition, half received 100%, half 60% reinforcement, until each reached 50 reinforcements. Shift period was 80 trials; half the Ss were reinforced for reversal, half for nonreversal shift. In acquisition and shift period, PRE was found. Reinforcement for placement or reason differed significantly. Reversal or nonreversal shift gave inconclusive evidence concerning mediation theory. A theory of verbal control accurately predicted correct placements from verbalized reasons. Number of nonreinforced acquisition trials correlated negligibly with shift-period response measures.

Investigations concerned with partial reinforcement of the stimulus dimension relevant during acquisition of a concept by human Ss have yielded rather complex results. Evidence regarding the existence of a partial-reinforcement effect (PRE) remains in several respects negative or inconclusive.

Buss (1952) found less resistance to extinction after partial reinforcement (50%) than after continuous. He noted that the experiment differed from a standard extinction experiment in that the response was attached to a new stimulus while being extinguished on the first. Still he could find no obvious explanation for the prolonged extinction after continuous reinforcement.

Sax (1960) utilized the same percentages of reinforcement as Buss and four delays of reinforcement. His measure of habit strength at the end of acquisition was the number of trials needed to reach a criterion of perfect performance. Neither schedule of reinforcement nor its interaction with delay of reinforcement proved to be significantly related to this measure. Retention after 2 wk. rather than a standard extinction procedure was the second measure of habit strength. Schedule of reinforcement was found to be unrelated to this measure also.

Erlebacher and Archer (1961) found that, as percentage of reinforcement increased (25%, 50%, and 100%) during acquisition, number of correct responses, number of errors, and total number of responses decreased. Their Ss were required to reach a degree of learning defined by a criterion of 10, 20, or 40 consecutive correct responses. They considered a nonreversal shift analogous to an extinction condition.

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and hypothesized accordingly that number of perseverative errors would be inversely related to percentage of reinforcement. This second aspect of PRE was not confirmed, although there did appear a significant interaction between percentage of reinforcement and degree of learning, with perseverative errors as the response measure. During acquisition, however, increase in percentage of reinforcement was confounded with a decrease in number of reinforcements—a problem in partial-reinforcement studies to which Kanfer (1954) has called attention. In the present instance, it renders the negative results and the already complex interaction difficult to interpret.

The analogy of reversal and nonreversal shifts to an extinction condition makes the relative difficulty of the two types of shift relevant. Kendler (1960) has reviewed the evidence that the majority of adult Ss learn a reversal shift rather than a nonreversal shift. The former requires a shift only in the overt response and not in the postulated mediating response, and this accounts for its relative facility. Mediation theory also predicts positive transfer in a reversal shift as compared with a control, but Isaacs and Duncan (1962) have obtained negative results. It is also of interest to inquire whether PRE can be found when reinforcement is applied to verbal rather than motor responses. A design which can be adapted to test such a hypothesis has been presented by Verplanck (1962). He found evidence of the dissociation of motor (card placements) and verbal (trial-by-trial hypotheses) responses under partial reinforcement (60%) after acquisition under continuous reinforcement. Dulany (1962), on the other hand, has presented a theory of verbal control which predicts no dissociation under such conditions, and Dulany and O'Connell (1963) have presented evidence to the same effect from a replication of Verplanck's research.

In both the Sax (1960) and Erlebacher and Archer (1961) studies, the failure to control for the number of reinforcements made the meaning of the negative results regarding PRE in the second phase of the experiments unclear. Moreover, Sax used a retention measure, and Erlebacher and Archer used only a nonreversal shift. In this study, it is expected that PRE will be verified in both acquisition and shift period, with reinforcement contingent on motor or verbal responses. The negative findings of Isaacs and Duncan (1962) suggest the further hypothesis that reversal and nonreversal shifts will not prove significantly different. Finally, dissociation of placement and reason is expected in none of the conditions in consequence of the various reinforcement contingencies.

**Method**

**Stimuli.** A set of 320 3 X 5 in. cards was used. The figures thereon differed along four dimensions: shape (20 different kinds), position (top or bottom of the card), color (red, black, blue, or green), and number (one or two figures per card). Order of presentation was the same for all Ss; each block of 20 cards had one card with each of the 20 figures, 5 of each color, 10 with figures in the top and bottom positions, respectively, and 10 with one and two figures, respectively. Within each block, order of presentation was randomized.

One block of 20 cards served as a sample for S during instructions, and an extra card covered the deck. The other 300 cards were piled face up in order before S. To the left and right were receptacles for the cards.

**Subjects.** The sample consisted of students in an introductory psychology course. The 20 Ss in each of the eight experimental conditions were randomly assigned.
Procedural.—Each $S$ was scheduled individually for an hour. He was seated at a table with $E$ at his side and somewhat behind him. A screen hid $E$'s data sheets. Instructions were as follows:

The experiment you're helping me with is essentially a card sorting task; the cards can be sorted systematically into two stacks in a number of ways. You are simply to take each card in turn, decide whether to place it on the right or left stack, and give the reason why the card should be so placed. Tell me your reason in the following way: "—figures go to the right (left)." Meanwhile place the card accordingly and take the next card. The blank space is to be filled in with a single word descriptive of the card. Your reason might be, for example, "Green figures go to the left," or "Triangular figures go to the right." What are the real reasons are you must find out for yourself in the course of the experiment. I will reply with either "yes" or silence after each trial. You are to try to get as many "yeses" as possible. Here are some sample cards from the deck. Look through them to familiarize yourself with the type of card you will be dealing with during the experiment. Now to make sure you understand how the cards can be sorted into two piles, notice that the samples include green figures, red figures, black figures, and blue figures; single figures and double figures; top figures and bottom figures; and a number of types of figures, or shapes. These are the dimensions you are to use in filling in the blank space in the formula when you give your reasons.

The $S$'s questions were then answered, examples of all possible logical reasons were given with the extra card, and $S$ was reminded of the nature of his task. He then proceeded through the cards, pacing himself and without interruption, and filled out a brief post-experimental questionnaire.

Conditions.—Throughout the experiment, the P group (80 $S$s) were reinforced ("yes" from $E$) for correct placements irrespective of their reasons; the H group (80 $S$s) were reinforced only if the reason for their placement was exactly correct. During acquisition, each group was subdivided into groups with 100% and 60% reinforcement, respectively. In the latter group, $E$'s "yeses" were given in a randomized three out of each series of five correct responses (placements or reasons). Acquisition lasted until $S$ had been reinforced 50 times. Then all groups were shifted without notice to 100% reinforcement and subdivided into reversal- and nonreversal-shift groups for 80 more trials.

During acquisition, correct placements were: cards with one figure to the right; cards with two figures to the left. During the shift period, correct placements for the reversal-shift group were: cards with one figure to the left; cards with two figures to the right. For the nonreversal-shift group, they were: cards with figures at the top to the right; cards with figures at the bottom to the left.

Supplementary conditions.—An additional 30 $S$s, volunteers from Harvard and Radcliffe Colleges, were assigned to several of the experimental conditions in order to obtain further evidence regarding verbal control. From the instructions above, the sentence requiring that a single word be used, the sentence beginning "What the real reasons are," and the last two sentences were deleted. Twenty $S$s were assigned to the P group and evenly subdivided into groups with 100% and 60% reinforcement, respectively. The group with 100% reinforcement was given acquisition and nonreversal-shift trials; the group with 60% reinforcement was given acquisition trials only. The remaining 10 $S$s were assigned to the H group and given acquisition trials with 60% reinforcement.

Results

Learning during acquisition.—A number of response measures indicated terminal level of learning in each of the four acquisition groups: number of $S$s whose last 20 placements were all correct; number of $S$s whose last 20 reasons were all correct; mean number of correct placements in the last 20 trials for all $S$s; and mean number of correct reasons in the last 20 trials for all $S$s. For all these response measures, the differences between the 100% and 60% reinforcement conditions were significant in both P and H groups.

The binomial test was applied to the differences in number of $S$s whose last 20 placements were all correct: for the H groups (39 and 14), $p < .001$; for the P groups (26 and 2), $p < .001$. The binomial test was similarly applied to the differences in number of $S$s whose last 20 reasons were all
correct: for the H groups (35 and 9), \( p < .001 \); for the P groups (23 and 1), \( p < .001 \).

The \( t \) test was applied to the mean number of correct placements in the last 20 trials for all Ss: for the H groups (19.95 and 17.95), \( t (38) = 4.47, p < .01 \); for the P groups (18.02 and 14.52), \( t (38) = 4.32, p < .01 \). The \( t \) test was similarly applied to the mean number of correct reasons in the last 20 trials for all Ss: for the H groups (19.72 and 15.82), \( t (38) = 5.93, p < .01 \); for the P groups (14.95 and 5.95), \( t (38) = 6.55, p < .01 \).

Learning during shift period.—The main response measures for the shift period were: correct placements, correct reasons, perseverative reason errors, and perseverative placement errors. Means are presented summarily in Table 1.

A 2 \( \times \) 2 \( \times \) 2 factorial analysis of variance for correct placements indicated two significant main treatment effects: for the PRE, \( F (1, 152) = 93.09, p < .01 \); for the H-P effect, \( F (1, 152) = 16.14, p < .01 \). Parallel results were found in the analysis for correct reasons: for the PRE, \( F (1, 152) = 77.03, p < .01 \); for the H-P effect, \( F (1, 152) = 40.67, p < .01 \).

In both these analyses, Bartlett's test indicated heterogeneity of variance: \( \chi^2 (7) = 26.18, p < .01 \); and \( \chi^2 (7) = 27.82, p < .01 \). Hence the level accepted as significant was .01 in both instances (Lindquist, 1953).

In the analysis for perseverative reason errors, however, a transformation (log of score plus one) was effective in eliminating heterogeneity. In this analysis, the significant results were: the PRE, \( F (1, 152) = 69.97, p < .01 \); the H-P effect, \( F (1, 152) = 4.29, p < .05 \); the reversal-nonreversal effect, \( F (1, 152) = 5.83, p < .05 \); and the triple interaction, \( F (1, 152) = 6.10, p < .01 \).

The experimental design allowed only half as many perseverative placement errors in nonreversal as in reversal conditions. Hence a direct comparison of these conditions was not feasible, and two separate 2 \( \times \) 2 factorial analyses were required. In the analysis for reversal conditions, the two main treatment effects were significant: for the PRE, \( F (1, 76) = 52.26, p < .01 \); and for the H-P effect, \( F (1, 76) = 12.05, p < .01 \). In the analysis for nonreversal conditions, only one main treatment effect was significant: for the PRE, \( F (1, 76) = 63.27, p < .01 \). In the analyses for both reversal and nonreversal conditions, Bartlett's test indicated heterogeneity of variance: \( \chi^2 (3) = 13.85, p < .01 \); and \( \chi^2 (3) = 20.61, p < .01 \). Again, the level accepted as significant was .01 because of the heterogeneity.
Similar comparisons were made by applying the binomial test to the number of Ss in the various conditions to reach 10 or more successive correct placements or correct reasons. In terms of both criteria, the PRE was significant (73 and 40; 69 and 34), $p < .01$, as was also the H-P effect (70 and 43; 69 and 34), $p < .01$. The frequencies for the reversal-nonreversal effect (56 and 57; 55 and 48) were not significant.

The number of Ss whose first shift in reason during the shift period was a reversal was significantly different in the H and P conditions (38 and 11) by the binomial test, $p < .001$. This result is hardly surprising, since learning of reasons during acquisition reached a higher level in the H than in the P conditions. The number of Ss in the H condition whose first shift in reason during the shift period was a reversal and nonreversal, respectively (38 and 41) was then compared by means of a $2 \times 2$ contingency table with the frequencies for these same reasons in the initial responses of the experiment (41 and 86). The shift-period frequencies were found to be significantly different from the expected frequencies: $x^2 (1) = 16.86$, $p < .001$.

**Verbal control.**—Miscategorizations (S named a figure erroneously, e.g., called a green figure red) occurred on only 6, or .02% of the 29,874 trials of the experiment. Misplacements (S placed card on one side while saying he was placing it on the other side) occurred on 58, or .19% of the trials. Misplacements for the 100% and 60% reinforcement conditions during acquisition were 25 and 10, respectively. However, the larger figure was contributed to by multiple misplacements of several Ss. The cumulative distributions of Ss making various numbers of misplacements in these conditions were compared by means of the Kolmogorov-Smirnov two-sample test, and the differences proved nonsignificant: $D = .0875$, $p > .10$.

A formula for expected correct placements ($P_E$) was adapted from Dulany and O'Connell (1963). It relies on the following assumptions: Correct reasons control correct placements; Incorrect reasons control incorrect placements; Irrelevant reasons control correct and incorrect placements with equal frequency. Correlated reasons (e.g., reasons correct but for the addition of superfluous elements) had proved an important component of the original formula, but were excluded from the adapted formula because Ss were free to use only a single word descriptive of the card in their reasons. This constraint was introduced in order to limit the experimental time for each S to 1 hr. and avoid nonlearners. Without such a constraint, Verplanck (1962) and Dulany and O'Connell (1963) had found it necessary to discard 17 and 25 Ss, respectively.

Correct and incorrect numerical reasons were coded as $H_N$ and $H_n$, respectively; correct and incorrect position reasons as $H_P$ and $H_p$, respectively. Irrelevant color and shape reasons were coded as $H_C$ and $H_S$, respectively. For conditions in which the correct reason was numerical, the adapted formula was:

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P_E = H_N + .5(H_C + H_S + H_P + H_P)
$$

For conditions in which the correct reason involved position, the adapted formula was:

$$
P_E = H_P + .5(H_N + H_n + H_C + H_S)
$$

The $t$ test for related measures was applied to the differences between expected and observed placements for each of the four acquisition and eight
shift-period conditions. In three acquisition conditions, the differences proved significant: for the 60% H condition, $t(39) = 3.62, p < .001$; for the 100% P condition, $t(39) = 3.68, p < .001$; and for the 60% P condition, $t(39) = 4.70, p < .001$.

One of the shift-period conditions proved significant: for the nonreversal 100% P condition, $t(19) = 2.11, p < .05$.

Nonreinforced trials during acquisition.—For each condition, correlations were computed between number of nonreinforced trials during acquisition and each response measure of the shift period: correct placements, correct reasons, perseverative reason errors, and perseverative placement errors. Of the 32 correlations, 7 proved significant, and of these, 2 were positive, 5 negative. They were distributed over conditions with no discernible regularity, even in the case of perseverative errors, for which the analogy to a standard extinction condition is most relevant.

Supplementary conditions.—For these data, the original formula for expected correct placements (Dulany & O'Connell, 1963) was applicable. Lifting the restriction to a single word in filling in the blank space made it necessary to discard 10 nonlearners; but it also made it possible for S to verbalize reasons which, although too specific to be scored as logically correct, could be expected to have a perfect positive correlation with correct placements. The $t$ test for related measures was applied to the differences between expected and observed placements for the three supplementary acquisition conditions and the one supplementary nonreversal-shift condition. These were the very conditions for which the $t$ tests proved significant in the results of the main experiment, and yet none of the $t$ tests in the present instance even approached significance.

### Discussion

Partial-reinforcement effect.—The present results clearly indicate PRE in both acquisition and shift period. Every one of the placement and reason response measures indicates the effect at the .01 or .001 level of significance. During acquisition, terminal level of training is consistently higher under continuous than under partial reinforcement. During the shift period, resistance to extinction is consistently higher in the group which had partial reinforcement during acquisition than in the group which had continuous reinforcement during acquisition.

Lawrence and Festinger (1962) have recently rejected the explanation of PRE in terms of contrast between acquisition and extinction trials and explained the phenomenon as a function of the total number of unrewarded trials. In the results of the present experiment, however, there are no significant correlations between number of nonreinforced trials during acquisition and any response measure for the shift period which disclose such a systematic or consistent relationship. The few correlations which did prove significant reflect the trivial fact that individual Ss are consistently good or poor in their performance during acquisition and the shift period. It should be noted, however, that the similarity of shift periods to an extinction condition is analogous; the evidence found in this experiment cannot be extended to a standard extinction condition in every respect without further evidence.

Reversal and nonreversal shifts.—The evidence of the present experiment does not lend support to the hypothesis that a reversal shift will yield faster or better learning than a nonreversal shift. Only the analysis for perseverative reason errors yields a significant reversal-nonreversal effect, but a study of the means in Table 1 shows that the largest reversal-nonreversal differences appear in the partial-reinforcement groups. Duncan's
multiple-range test shows that these are also the differences which account for the significant effect. In terms of the mediation hypothesis, this would mean that, where the mediator was learned poorly during acquisition, reversal and nonreversal shifts differentiate subsequent levels of learning the better; where the mediator was learned well, there appear no significant differences between the reversal and nonreversal groups. Even this isolated significant result is, therefore, exactly the opposite of what the mediation theory would hypothesize.

It is plausible to suggest that the failure to find significant differences between reversal and nonreversal shifts might be a consequence of the different salience of the dimensions relevant in the two stages of the experiment. Since these dimensions were not varied, they were indeed confounded with the shift variable; the relevant dimensions for reversal and nonreversal shifts were always numerical and positional, respectively. If position were a more salient dimension than number, the nonsignificant result could be expected. But the initial responses of the experiment indicate no such salience. On the contrary, 74 Ss gave numerical reasons as their first response, and only 19 gave positional reasons. Hence, the salience of the relevant dimensions would have inflated any difference in favor of reversal shift over nonreversal shift.

The evidence does support the mediation hypothesis, however, insofar as the number of Ss in the H condition whose first shift in reason was a reversal was significantly greater than expected in accord with the salience of these same reasons in the initial responses of the experiment. Apart from the salience of dimensions, we should expect only 11 reversal-shift responses rather than the 38 observed in the 79 first shifts in reason, if a reversal shift occurred only as frequently as each of the other six available (nonreversal) shifts. The preponderance of reversals among these first shifts in reason is, therefore, all the more impressive.

Verbal control.—Dulany and O'Connell (1963) found that miscategorizations accounted for what appeared to be dissociation in Verplanck's research. And the miscategorizations were due in turn to ambiguous stimuli. No miscategorizations occurred in their control experiment with unambiguous stimuli. In the present experiment, miscategorizations and misplacements do occur, but so minimally as to have little effect on the accuracy of the formula for expected placements.

But the adapted formula does not accurately predict in all cases. The failures in prediction can well be ascribed to the inadequacy of the formula and the corresponding constraints placed upon the experimental design, rather than to any weakness inherent in a theory of verbal control as such. This suggestion is convincingly borne out by the results of the supplementary conditions. When Ss were allowed to verbalize correlated reasons, they did so on 27% of the trials. And when these correlated hypotheses were in turn taken into account in the original formula for expected correct placements, all the significant differences between expected and obtained correct placements disappeared. It is clear that the adapted formula did not provide adequate evidence of verbal control precisely because Ss could entertain hypotheses which they were not allowed to verbalize. The constraints placed on verbalization served only to preclude the possibility of gathering adequate evidence regarding verbal control.

In both acquisition and shift period, therefore, with reinforcement contingent on either verbal or motor responses, PRE can be found in concept learning. No dissociation due to reinforcement contingencies was found, and evidence regarding the relative facility of reversal and nonreversal shifts was mixed.

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