Discrimination learning by preschool-aged children based on secondary reinforcement established by differential and nondifferential training under two percentages of primary reinforcement.

DISCRIMINATION LEARNING BY PRESCHOOL-AGED CHILDREN BASED ON SECONDARY REINFORCEMENT ESTABLISHED BY DIFFERENTIAL AND NONDIFFERENTIAL TRAINING UNDER TWO PERCENTAGES OF PRIMARY REINFORCEMENT

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DISCRIMINATION LEARNING BY PRESCHOOL-AGED CHILDREN BASED ON SECONDARY REINFORCEMENT ESTABLISHED BY DIFFERENTIAL AND NONDIFFERENTIAL TRAINING UNDER TWO PERCENTAGES OF PRIMARY REINFORCEMENT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Resistance to extinction has frequently been employed as the experimental criterion for establishment of secondary reinforcing properties in a neutral stimulus (Beck, 1960; Myers, 1958).[1] In contrast to this experimental emphasis on the role of secondary reinforcers in maintaining previously established stimulus-response relationships, the emphasis of theoretical treatments (Wyckoff, 1959; Zimmerman, 1957) and explanatory uses (Dollard & Miller, 1950) of the concept of secondary reinforcement has been the role of secondary reinforcers in establishing new stimulus-response relationships. In view of the theoretical and explanatory importance of factors underlying the role of secondary reinforcers in strengthening new stimulus-response relationships, considerable additional data on such factors are required. Within this general objective, the present study investigated discrimination learning by preschool-aged children as a function of differential and nondifferential training with a PSR under two percentages of occurrence of primary reward. Differential training involves presentation of a PSR only on trials during which primary reward occurs,

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1. A primary reinforcer is here defined as a stimulus with initial reward value for a particular subject (S) in a particular situation, something for which the S will initially learn to respond without prior experimental training. A secondary reinforcer is defined as a stimulus having little or no initial reward value, which acquires reward value through pairings with a primary reinforcer. Prior to a demonstration of acquisition of reward value by a stimulus, that stimulus is a potential secondary reinforcer (PSR) or a neutral stimulus.

while nondifferential training involves presentation of a PSR on all trials, regardless of occurrence of primary reward. Theoretical considerations and findings of previous experiments suggest that training procedures and percentages of occurrence of primary reward should be important determinants of the secondary reinforcing properties of the PSR.

Wolfe (1936) and Cowles (1937) have demonstrated that stimuli previously paired with primary reinforcers could be used to strengthen new stimulus-response relationships. Cowles trained hungry chimpanzees to exchange tokens for food; these tokens were then used to reward correct responses on discrimination tasks. Tokens which had not been previously paired with food did not serve as reinforcers.

Once the phenomenon of secondary reinforcement is demonstrated, the concern is identifying and determining the relative importance of variables which influence the acquisition in PSRs of secondary reinforcing properties. In a theoretical analysis of conditions necessary for the establishment of strong secondary reinforcers, Zimmerman (1957) emphasized following the PSR by an increasingly intermittent primary reinforcer and then using the PSR intermittently as a consequence of the response which its presentation was to strengthen. The experiment which Zimmerman described is the first of a series of experiments which have used the nondifferential training procedure. Thirsty rats were trained to respond to a buzzer in order to obtain water. Occurrences of the primary reinforcer were gradually reduced to 10% of the presentations of the buzzer. Subsequently, a bar was introduced with the buzzer sounded according to a fixed-interval schedule; water presentations no longer occurred. The frequent and persistent bar pressing which occurred indicated that the buzzer had become a strong secondary reinforcer.

In a test of the relative effectiveness of continuous and partial pairings of the PSR and a primary reinforcer, Fox and King (1961), using hungry rats as Ss, paired a buzzer with food presented on 100% or 10% of the trials. The bar presses of one third of the Ss from each of these groups were then reinforced by presentation of the buzzer following 0%, 10%, or 100% of the presses. Partial occurrence of food in training and of the PSR in testing produced the strongest secondary reinforcement effect.

D'Amato, Lachman, and Kivy (1958) trained one group of hungry rats to run to a goal box in which food was always present; another group ran to a goal box in which food was present on only 50% of the trials. Secondary reinforcement effects were tested by administering 30 non-rewarded trials in a T-maze in which one arm terminated in the goal box, and the other arm led to a novel box. During the last 15 trials, rats trained on a 50% schedule of reward showed a greater preference for the goal box than did rats trained on a 100% schedule. Boyle (1961) replicated these results in a U-maze.

Klein (1959) trained six groups of rats to run to a goal box in which food was present on 100%, 90%, 80%, 60%, 40%, or 20% of the trials. In a subsequent 20-trial T-maze test using the goal box and a novel box, preference for the training goal box was greatest in those groups trained with lower percentages of primary reward.

In these studies, the PSR was presented on all trials regardless of occurrence of the primary reinforcer; the training was nondifferential. These studies indicate that a PSR can acquire secondary reinforcing properties with a nondifferential training procedure, and that the effectiveness of the PSR as a secondary reinforcer is stronger when the primary reinforcer in training and the PSR in testing are presented on highly intermittent schedules. Differential training is an alternative procedure for establishing a secondary reinforcer in the presence of partial primary reinforcement; the PSR is presented only on rewarded trials during training.

McGuigan and Crockett (1958) investigated the establishment of secondary reinforcement by using a differential training procedure. In their study, some of the running responses of one group of rats were to a goal box in which food was present; other responses were to a different goal box in which no food was present. All of the running responses of a second group led to a goal box with food. Differential training produced a greater preference for the previously rewarded box than did continuous reinforcement training.

In contrast to the above differential procedure, Armus and Garlich (1961) used a differential technique in which no stimulus was presented on non-rewarded trials. In the differential training condition, 20% of the bar presses by rats were followed by the sound of the food dispenser and a flash of light, and then by food. In the continuous reinforcement condition, each bar press was followed by the sound-light stimulus, then food. In the testing period, an additional lever was introduced. One lever produced the sound-light stimulus, the other produced no stimulus change. The lever producing the sound-light stimulus was chosen more frequently by rats trained under the 20% pairing of PSR and food than by those trained under the continuous condition.

These studies indicate that differential training is also an effective technique for establishing secondary reinforcing properties which will strengthen new stimulus-response relationships. However, the relative effectiveness of the nondifferential and differential training procedures has been compared in only one experiment. Saltzman (1949) trained rats to run down a straight alley to a distinctive goal box. The rats in a "consecutive reinforcement" group found food in the goal box after every run, while those in an "alternate reinforcement" (nondifferential) group found food on about 60% of the trials, and, on other trials, entered the same goal box, but found no food. The rats in a "differential reinforcement" group also found food on about 60% of the trials, but on the remaining ones, entered a discriminably different goal box in which there was no food. The test for secondary reinforcement was 15 non-rewarded trials in a U-maze in which one arm led to the goal box in which food had been found, the second arm to a box in which food had not been found. All groups chose the arm which led to the training goal box in which food had been found significantly above chance expectancy, the differential reinforcement group showing the greatest preference, significantly above the preferences of the other groups.

The present study extended Saltzman's experiment in three ways. First, the effectiveness of differential and nondifferential training procedures were compared at two levels of partial primary reinforcement, one approximately the same as that used by Saltzman (60%), the other considerably lower (20%). Second, Saltzman's original differential training group (hereafter called D-1) was supplemented by the differential training procedure (called D-2) in which the PSR occurs after those responses followed by primary reward, but no stimulus change occurs on non-rewarded responses. The third extension was the use of preschool-aged children, rather than rats, as Ss.

Only Klein determined the effects on secondary reinforcement of several percentages of primary reinforcement, and the percentage he found optimal was considerably lower than that used by Saltzman. Two percentages of occurrence of primary reward were introduced in the present study to provide additional information about the effects of this variable on both nondifferential training and the two forms of differential training. Use of the lower percentage also permitted determination of the generality of Saltzman's observation of a difference in effects of the differential and nondifferential training procedures. The D-2 training procedure was included to provide data on the relative effectiveness of this additional technique, when compared to the D-1 procedure; this technique should permit evaluation of the importance of pairing the non-secondary reinforcing test stimulus with non-reward during training.

Children were chosen as Ss to supplement data previously obtained only from subhumans. The extension of learning experiments with animals to experiments with humans is an essential step in the understanding of human behavior. Children were chosen rather than adults, because presumably, they have been exposed to fewer experiences than the adult, and have less complicated behavioral processes.

The present study, then, had three objectives: (a) to provide information concerning the establishment and maintenance of secondary reinforcement effects on developing new stimulus-response relationships in human beings; (b) to provide a more extensive comparison of the differential and nondifferential training procedures, including a differential procedure not previously compared with nondifferential training; and (c) to provide additional data on the effects of intermittent schedules of primary and potential secondary reinforcer presentation.

METHOD

Experimental Design

Table 1 summarizes the experimental design. Pressing a button led to presentation of a PSR (red or green light) which was followed by a primary reinforcer (chocolate covered candy, M & M's) on 20% or 60% of the presses. Both schedules were used with the nondifferential (ND) and the D-1 and D-2 forms of differential training. The groups were counter-balanced with regard to the color of the PSR in training and its position in testing. One-half of the Ss in each group was trained with the red as the PSR while the other half was trained with green. One-half of each of these groups was presented the PSR in response to the top button in the testing period, while the other half found it in response to the bottom button. The details of the training and testing conditions for the control group and the six experimental groups were as follows:

Continuous Reinforcement Group (Control): The Ss in this group had the candy and the PSR paired on each of their 15 training trials. In the testing period, one button produced the PSR, while the other button led to the presentation of a novel light, i.e., the one not previously seen in training.

60% First Differential Reinforcement Group(D-1-60): The Ss in this group were trained with 60% primary reward. They received the PSR and candy on 15 out of a total of 25 training responses. These Ss also received a different light on the remaining 10 responses which were not followed by candy. In the testing period, they chose between the button resulting in the PSR and the button resulting in the light associated with non-reward.

Table 1

Summary of Experimental Design

Experimental Procedures	Percentage of Occurrences of Primary Reward in Training	Color of PSR in Training				Total Number of Ss for Each Group
		Red		Green		
		Position of PSR in Testing				
		Top	Bottom	Top	Bottom	
D-1	20%	4Ss*	4	4	4	16
	60%	4	4	4	4	16
D-2	20%	4	4	4	4	16
	60%	4	4	4	4	16
ND	20%	4	4	4	4	16
	60%	4	4	4	4	16
Control	100%	4	4	4	4	16

* Number of Ss in each subgroup to counterbalance for color of PSR in training and position of PSR in testing

20% First Differential Reinforcement Group (D-1-20): The Ss in this group received the same treatment as those in the D-1-60 group with the exception that their primary reward was presented on a 20% schedule. They were presented the PSR and candy following 15 responses and received a different light on the 60 responses after which candy was not given. The testing conditions were the same as those of the D-1-60 group.

60% Second Differential Reinforcement Group (D-2-60): The Ss in this group received the PSR and candy following 15 of 25 responses. They received no experimental stimulus change following the remaining 10 non-rewarded responses. In the testing period, these Ss chose between the button resulting in the PSR and the one resulting in a novel light.

20% Second Differential Reinforcement Group (D-2-20): The Ss in this group were trained in the same way as those in the D-2-60 group except for the difference in the percentage of primary reward. The PSR and candy were presented following 15 of 75 responses. There was no experimental change on the remaining 60 non-rewarded responses. When the testing period was begun, these Ss also chose between the button resulting in the PSR and one resulting in a novel light.

60% Nondifferential Reinforcement Group (ND-60): The Ss in this group received candies following 15 of 25 training responses, while the PSR was received after each response. In the testing period, one button led to the presentation of the PSR while the second led to a novel light.

20% Nondifferential Reinforcement Group (ND-20): The Ss in this group received the same treatment as those in the ND-60 group with the exception that their primary reward was presented on a 20% schedule. They were allowed 15 candies out of the 75 responses and PSR presentations. The testing conditions were the same as those for the ND-60 group.

Apparatus

The apparatus consisted of three units: a stimulus box, a control unit, and a Western Union Tape Transmitter. On the front of the stimulus box were three translucent windows, three buttons, and a slot tray. To minimize any bias due to hand preferences, the windows and buttons were arranged vertically, the windows in a column on the right, and the buttons on the left. The slot tray was located at the bottom center of the box. Any pair of plates and buttons could be concealed from the view of the S by attaching sliding masonite panels to the front of the box. A red and a green light bulb were placed behind each window, and when lighted, illuminated the window clearly, producing a distinct red or green stimulus, one of which was the PSR for each of the Ss. The candy primary reward was dispensed to the slot tray through a tube leading from a reservoir inside the unit.

The control unit of the apparatus contained electrical relays which operated the light and candy mechanisms, while the Western Union Tape Transmitter provided for automatic presentation of the schedules for the lights and candy.

Procedure

The procedure which follows was developed on the basis of preliminary experimentation. The children were contacted through the teachers of the kindergarten classes in the schools, and were told they would be allowed to "play a surprise game." Most children were enthusiastic and cooperated well.

The apparatus was located in a slightly darkened room as isolated as possible, to minimize distractions. The stimulus box was placed on a small chair within easy reach of the S, and against a blank wall. After preliminary conversation designed to put the child at ease, he was shown several "fairy tales charms,"[2] and told that if he played a game, he would be able to select one of the charms to take home and keep. His attention was then directed to the apparatus.

Training: For training, the top and bottom buttons and windows were concealed, and the experimenter (E) pressed the center button and received a candy from the slot tray. The S was then encouraged to try the button, after which the game was explained. For the D-1 and D-2 procedures, the explanation was: "You press this button, and when you do, sometimes a candy will come out, and just before it does, a green (or red) light will come on in this window. So, you press the button, and when a green (or red) light comes on you know you get a candy." For the ND procedure, the explanation differed slightly: "You press this button, and when you do, a green (or red) light will come on and sometimes you'll get a candy." For the Control group, the "sometimes" was omitted. The S was then told that he could stay and continue to play the game.

During the training period, the S saw and used only the center button and light, and was administered the appropriate reinforcement

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2. The charms are distributed by Samuel Eppy & Co., Inc. of Jamaica, Long Island, New York.

schedule until the end of the training period. The reinforcement schedules, which are reported in the Appendix, were random with the restriction that the first and last responses in training were accompanied by the PSR and primary reward, which was never presented without first being preceded by a 1-sec. presentation of the PSR.

Testing: Immediately after the last primary reward in training, each S was told he had earned his charm. He was then told there was another game he could play. The center button and light were covered, the top and bottom ones exposed. The E pressed each of the buttons once to demonstrate: a green light followed the press of one button, a red light followed the other. The S was informed that by staying and playing with the "right" button, he would be able to choose a second charm to keep, and was then told he could stay and play with the "right" button as long as he wanted. "Right" was never defined or commented upon further, unless the S continued to ask without beginning to play. When this happened, he was told to play with the button he thought was the right one.

Throughout the training and testing periods, the S was allowed to respond at his own rate. The testing period was terminated when the S indicated a desire to stop, or at the end of 10 minutes. At this time, the S was allowed to choose two charms, and return to the classroom.

Subjects

The Ss were 112 kindergarten children from the Northampton, Massachusetts school system.[3] They ranged in age from 5 years, 3 months,

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3. The author's appreciation is extended to Mr. William Barry, Superintendent of Schools and to Miss Esther Wien, Elementary School Supervisor, Northampton, Massachusetts, for cooperation in providing Ss and facilities for this study.

to 6 years, 6 months, with a mean age of 5 years, 8 months. Within the restrictions of equating the groups for age and for sex, the Ss were equally and randomly assigned to the seven groups.

RESULTS

The number of responses to the secondary reinforcement (S^r) and nonsecondary reinforcement (NS^r)[4] buttons made in each of five consecutive 2-min. intervals were recorded; the means and standard deviations of these intervals for the seven groups are presented in Table 2. The important features of the relationships among means in Table 2 are shown graphically in Figures 1, 2, and 3.

Figure 1 shows the mean number of responses followed by S^r and by NS^r during the entire 10 minutes. There is an important relationship among these means; the differences between choices of the S^r and NS^r buttons for the ND, D-1, and D-2 groups show a different pattern under the 20% schedule than under the 60% schedule. Under the 20% schedule, all groups evidenced a preference for the S^r button. The ND group evidenced the clearest preference, with a difference of 63.63 in mean number of responses to the two buttons. The second largest difference in responses to the two buttons was found in the D-1 group, which showed a mean difference of 30.00, while the smallest difference for the 20% groups was that of the D-2 group, which showed a difference of 13.06 mean responses. Under the 60% schedule of primary reward in training, the groups were ordered differently in mean difference in responses to the S^r and NS^r buttons. Here, the D-1 group evidenced the greatest preference for the S^r button with a mean difference between the two buttons of 62.81. The second largest difference

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4. The S^r button is that button which, when pressed, led to the presentation of the light which was previously associated with candy, the primary reward. The NS^r button is that button, which when pressed, led to the presentation of the light which was previously associated with non-reward for the D-1 group, and which was never seen by the <u>S</u>s in the D-2 and ND groups.

Table 2

Means and Standard Deviations of Responses to S^r and NS^r Buttons for Five 2-min. Intervals

Group	Block of Time	Responses to S^r Button		Responses to NS^r Button	
		Mean	Standard Deviation	Mean	Standard Deviation
	1	20.81	12.74	14.00	11.13
	2	18.75	11.88	13.06	12.89
D-1-20	3	18.12	15.83	11.37	13.71
	4	17.12	15.62	11.87	13.58
	5	16.56	17.32	11.06	14.04
	1	21.50	11.95	19.43	10.81
	2	22.31	13.10	18.93	11.41
D-2-20	3	20.93	13.37	17.37	9.84
	4	19.75	17.17	17.68	15.49
	5	17.87	16.66	15.87	14.57
	1	28.87	15.56	11.68	13.28
	2	26.37	19.37	9.18	12.26
ND-20	3	24.18	20.63	8.37	14.62
	4	19.00	19.10	11.25	15.45
	5	17.87	22.06	12.18	17.61

Table 2 (Continued)

Group	Block of Time	Responses to S^r Button Mean	Responses to S^r Button Standard Deviation	Responses to NS^r Button Mean	Responses to NS^r Button Standard Deviation
	1	22.06	13.11	13.37	13.02
	2	23.87	15.67	12.31	13.56
D-1-60	3	24.31	18.26	9.81	12.18
	4	23.56	17.99	9.62	12.04
	5	22.50	19.65	8.37	12.73
	1	15.06	12.25	18.25	14.32
	2	14.93	15.83	11.06	10.35
D-2-60	3	15.50	17.51	10.93	13.68
	4	15.12	17.93	12.00	14.46
	5	15.25	19.09	9.06	12.29
	1	18.12	14.51	16.31	12.83
	2	13.06	16.63	15.31	15.15
ND-60	3	12.81	16.29	13.75	13.26
	4	13.50	16.02	14.81	15.43
	5	12.50	15.18	14.06	14.99
	1	10.13	8.04	17.25	13.23
	2	9.25	24.25	16.44	13.82
Control	3	9.56	10.00	15.75	14.59
	4	9.94	8.91	16.94	14.83
	5	10.19	9.41	17.06	14.60

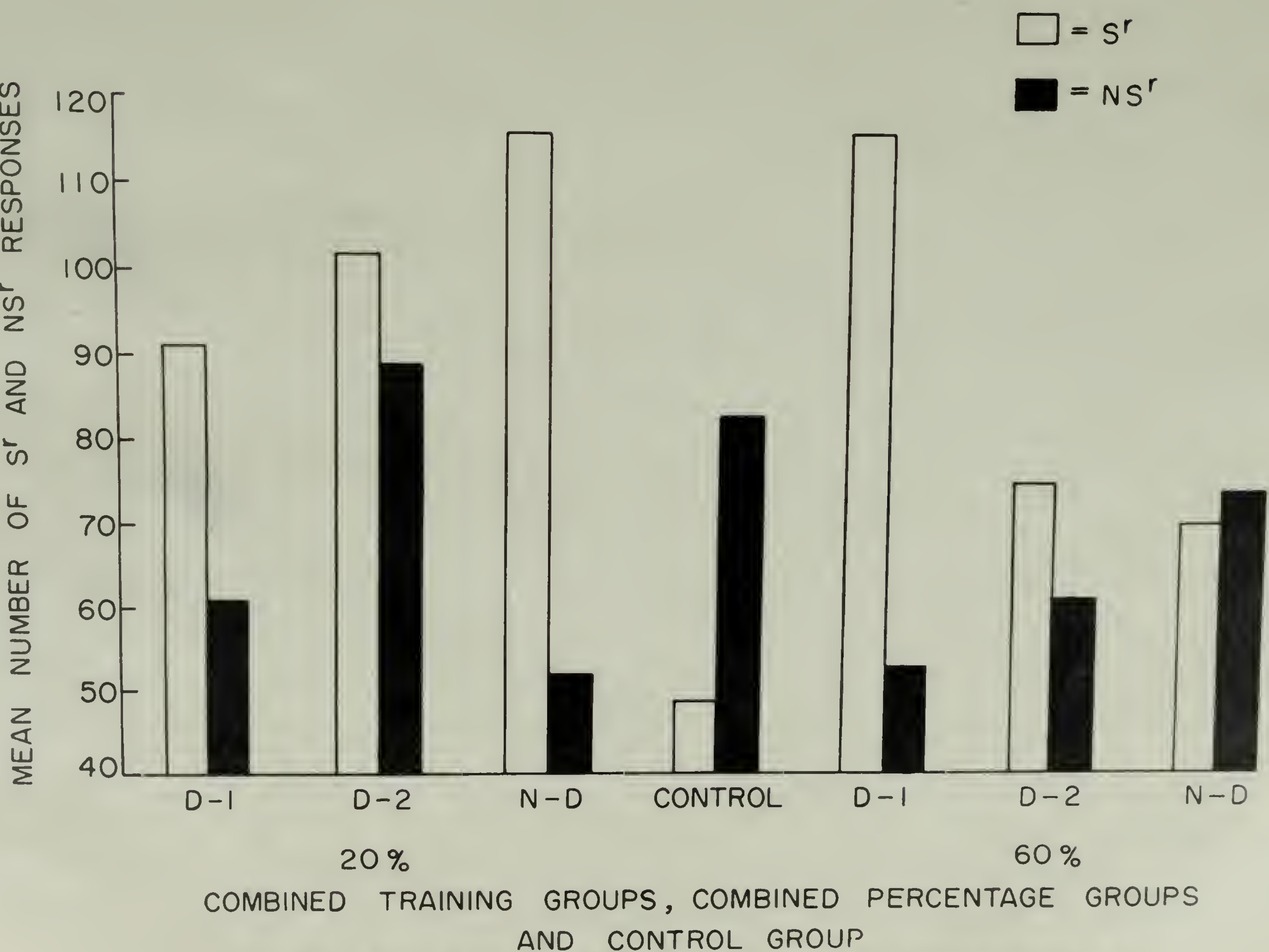

Figure 1. Mean Number of S^r and NS^r Responses in Discrimination for Combined Training Groups, Combined Percentage Groups, and Control Group

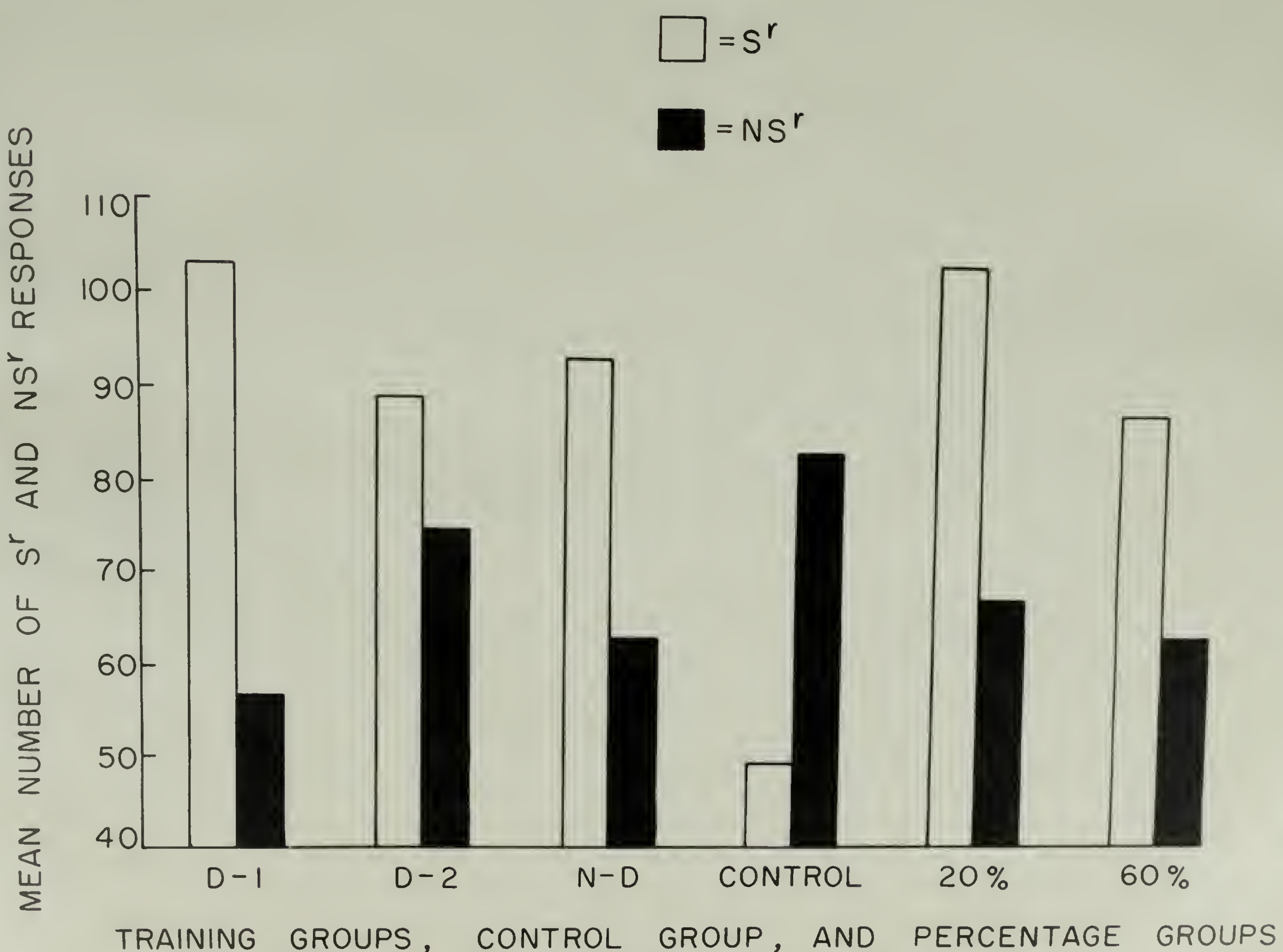

Figure 2. Mean Number of S^r and NS^r Responses in Discrimination for Training Groups, Control Group, and Percentage Groups

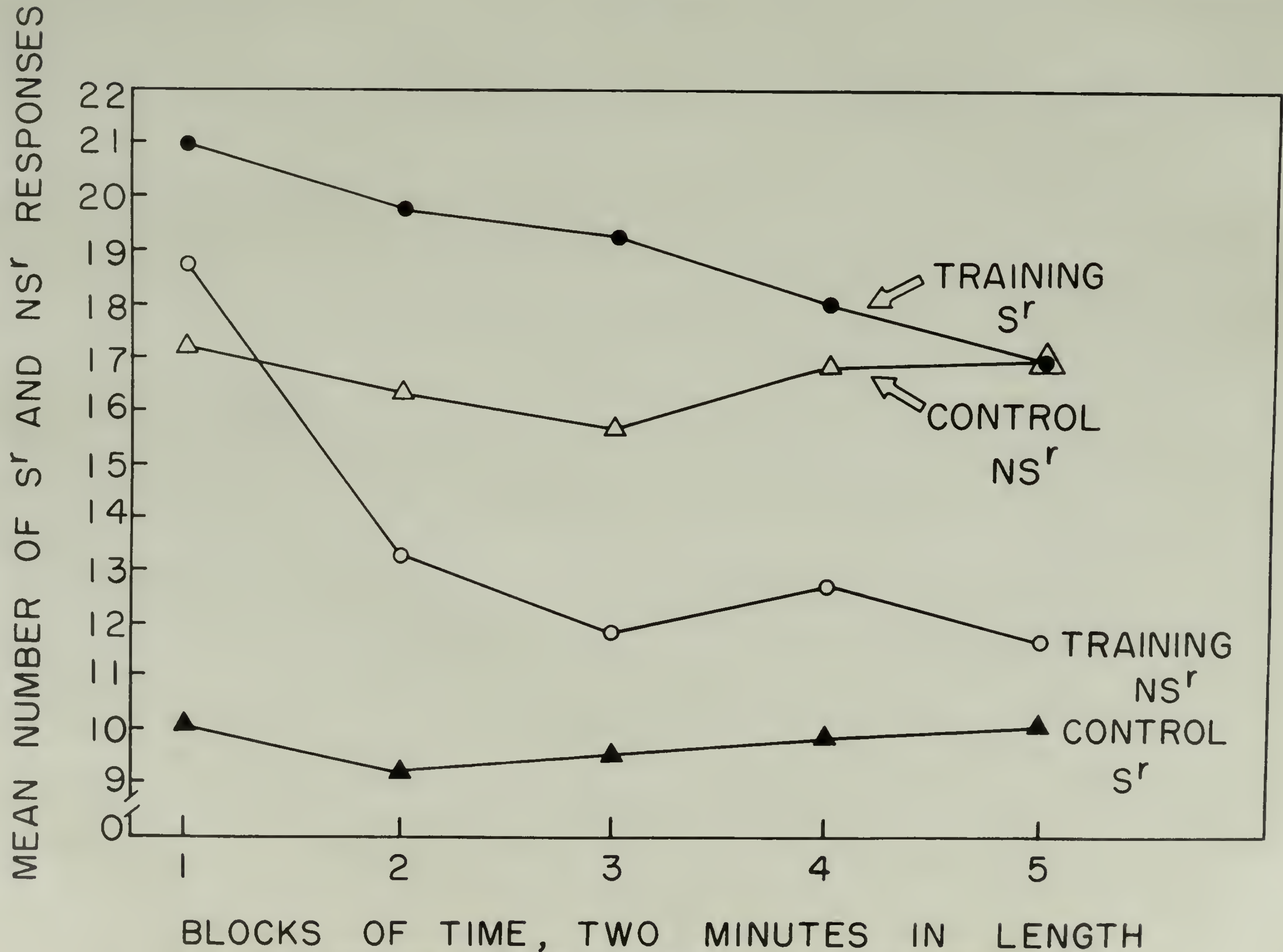

Figure 3. Mean Number of S^r and NS^r Responses in Discrimination for Five Blocks of Time, Two Minutes in Length

was found in the D-2 group with a mean difference of 14.56 in preference for the S^r button, while the ND group of the 60% schedule evidenced a slight preference for the NS^r button of 4.25 mean responses. The Control group also evidenced a preference for the NS^r button, yielding an average of 34.37 responses more to this button than to the S^r button.

Figure 2 also shows differences between the mean numbers of choices of the button followed by S^r and that followed by NS^r during the entire 10 minutes. However, the important feature here is the differences among the three training procedures, averaging over percentages of occurrence of the primary reinforcer, and differences among the two percentages, averaging over the three training methods. Data for the Control group are again presented. The mean differences in responses to the S^r and NS^r buttons for the training groups were, in order of magnitude, 46.40 for the D-1, 29.69 for the ND, and 13.81 for the D-2. The two reinforcement schedules yielded mean differences of 35.57 for the 20% and 24.38 for the 60% groups.

Trends over the five 2-min. intervals in mean number of responses to the S^r and NS^r buttons for the combined training groups and for the Control group are shown in Figure 3. Responding to the S^r button declined gradually over the 10 minutes, while responding to the NS^r button declined sharply during the first 4 minutes, then more gradually.

An analysis of variance performed on the total number of responses made to each button by the training groups during the 2-min. time intervals is summarized in Table 3. The significant F ($p < .025$) is consistent with the larger number of responses to the S^r button than to the NS^r button for five of the training groups. When the number of responses to the two buttons were combined, differences among training procedures, between training percentages and between

Table 3

Summary of Analysis of Variance for

Total Number of Responses in Testing

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F
Training (T)	2	98.855	49.427	.109
Percentage (P)	1	1031.265	1031.265	2.293
T x P	2	2067.885	1033.942	2.299
Ss/T x P	90	40466.035	449.622	
Secondary Reinforcement (S^r)	1	8622.008	8622.008	6.207*
T x S^r	2	1700.143	850.071	.611
P x S^r	1	300.387	300.387	.216
T x P x S^r	2	4248.354	2124.177	1.529
Ss x S^r/T x P	90	125010.616	1389.006	
Blocks of Time (B)	4	1629.860	407.465	8.217**
T x B	8	142.315	17.789	.358
P x B	4	79.315	19.828	.399
T x P x B	8	170.860	21.357	.430
Ss x B/T x P	360	17850.250	49.584	
S^r x B	4	173.574	43.393	.752
T x S^r x B	4	523.081	130.770	2.267
P x S^r x B	8	785.538	98.192	1.702
T x P x S^r x B	8	227.762	28.470	.493
Ss x S^r x B/T x P	360	20765.045	57.680	

* $p < .025$

** $p < .001$

the interaction of training and percentage were not significant. The Fs for T, P, and T x P are evidence for the lack of significance of these effects. The T x S^r, P x S^r, and T x P x S^r interactions test the significance of S^r effects as a function of training procedure, percentage and the joint effects of training and percentage. Contrary to the pattern of differences in responses to the two buttons suggested by Figures 1 and 2, the Fs were not significant. Although the differences among means were large, the error variance was also extremely large.

The decrement in total number of responses over blocks of time (B) shown in Figure 3 was significant at the .001 level. No interactions involving blocks were significant, suggesting that the discrimination between buttons was maintained at about the same level throughout the test period.

The results of a second analysis performed on the number of responses made to each button by the Control group are summarized in Table 4. The apparent differences in number of responses to the two buttons is not substantiated by the F for S^r ($p > .05$). Again, there were large individual differences in extent and direction of discrimination (Ss x S^r interaction). The combined responses to the two buttons indicate no significant change in response rate over the blocks of time. The lack of a significant S^r x B effect is evidence of the fact that the difference in number of responses to the two buttons was consistent for the length of the testing period.

Table 4

Summary of Analysis of Variance for Total Number of Responses by Control Group

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F
Subjects (Ss)	15	8931.80	595.45	95.42**
Secondary Reinforcement (S^r)	1	1890.62	1890.62	2.63
Blocks of Time (B)	4	28.31	7.07	.41
Ss x S^r	15	10766.38	717.75	
Ss x B	60	1026.89	17.11	
S^r x B	4	5.19	1.29	.20
Ss x S^r x B	60	374.81	6.24	

** $p < .001$

DISCUSSION

The results of the present study indicate that with preschool-aged children, just as with rats and chimpanzees, neutral stimuli paired with primary reinforcers by nondifferential and two forms of differential training procedures can function as secondary reinforcers to establish new stimulus-response relationships. Discussion of certain trends in the data seems warranted in light of the marked error variance in the statistical techniques used, and the large differences among groups in the relative number of responses made. It must be understood that these trends remain to be confirmed in more efficient experiments. Of particular interest are the indications that: (a) the ND-20 group evidenced better discrimination between the two buttons than did the ND-60 group in contrast to the better discrimination of the D-1-60 group than of the D-1-20 group; (b) the D-1 training procedure led to better discrimination than did the D-2 procedure; (c) the Control group evidenced a preference for the button followed by the novel light rather than the previously experienced PSR.

The first two findings are discussed in relation to their significance for the interpretation of secondary reinforcement in terms of a discrimination hypothesis and of a discriminative stimulus hypothesis. The preference for the novel stimulus shown by the Control group is considered in terms of its significance for experiments in which secondary reinforcement effects are based on continuous pairings with primary reward. Suggestions are made for future experimental procedures to eliminate some of the marked error variance.

Discrimination Hypothesis

According to the discrimination hypothesis (Mowrer & Jones, 1945) Ss find it difficult to discriminate between the onset of testing, when no reward is forthcoming, and the continuation of training where reward has been intermittent. The effect seems to be particularly pronounced when the percentage of reinforcement in training has been very low. The application of this hypothesis to the experimental conditions in the present study may become clearer if the components of the two periods, training and testing, are examined. For purposes of illustration, the green light will be the S^r, and the red the NS^r. In the testing period, the green light will be presented in response to the top button, the red light in response to the bottom. On 20% of the training trials, the ND-20 group found that: (1) instructions to press the middle button (S_m) led to (2) a response to the middle button (R_m), which produced (3) a green light (S_g), followed by (4) the response of approaching the slot tray (R_a), and (5) the presentation of candy (S_c). On the remaining 80% of the responses, (1) the instructions to press the middle button led to (2) a response to the middle button which produced (3) a green light, followed by (4) the response of approaching the slot tray. Here, the last stimulus component, that of candy presentation (5), was absent. These events may be seen schematically below:

Stimulus-response (S-R) chain	Percentage of occurrence following response	
(1) (2) (3) (4) (5)	ND-20	ND-60
S_m - R_m - S_g - R_a - S_c	20%	60%
(1) (2) (3) (4)		
S_m - R_m - S_g - R_a	80%	40%

In the testing period, when the (1) top button (S_t) led to (2) a response to the top button (R_t) it was followed by (3) a green light, then by (4) the response of approaching the slot tray. The fifth component, candy presentation, was absent. This testing sequence occurred on 100% of the responses which were made to the top button. When the (1) bottom button (S_b) led to (2) a response to the bottom button (R_b), it was followed by (3) a red light (S_r), and perhaps (4) the approach response to the tray. This sequence occurred on 100% of the responses made to the bottom button. The events for testing may be seen schematically as:

Stimulus-response (S-R) Chain	Percentage of occurrence following response	
(1) (2) (3) (4)	ND-20	ND-60
S_t - R_t - S_g - R_a	100%	100%
(1) (2) (3)		
S_b - R_b - S_r	100%	100%

It may be seen that the response sequence to the top button was very similar to the conditions which occurred on the majority (80%) of the training responses of the ND-20 group. Therefore, this group might be expected to find it difficult to distinguish between the consequences of the top button in the testing period, and those of the middle button used in training. According to the discrimination hypothesis, the Ss in the ND-20 group should respond to the top button which produces conditions most similar to those experienced in training. A significant preference for the S^r (top) button was obtained for this group. Since there was a greater discriminable difference between the 100% absence of reward in testing and its 40% absence in training, than there was between 80% and 100% in the ND-20 group, it follows that the ND-60 group should generalize less, between the middle and the top buttons, and therefore should evidence weaker discrimination between the two testing buttons. The results were in agreement with this expectation and with what would be expected on the basis of previously cited studies, since the nondifferential training procedure was essentially the same as that under which Zimmerman, Fox and King, and Klein found strong S^r effects.

An apparent second difference among groups is that between the D-1 training groups. On the basis of results from partial reinforcement studies, the 20% group might be expected to evidence a greater number of responses to the S^r button than the 60% group. However, no previous S^r study using the differential technique investigated the effects of more than one level of partial reinforcement. In the present study, the 60% group showed a greater difference in responses to the S^r and NS^r button than did the 20% group. If the S-R relationships which exist for the Ss in the training and testing periods are again considered, some support may be found for this trend in the data.

The D-1-60 group found that (1) instructions to press the middle button led to (2) a response to the middle button which produced (3) a green light, followed by (4) the response of approaching the slot tray, and (5) candy presentation on 60% of their training responses, and found that (1) instructions to press the middle button led to (2) a response to the middle button which produced (3) a red light, on 40% of their training responses. Shown schematically, those sequences were:

Stimulus-response (S-R) chain	Percentage of occurrence following response D-1-20	D-1-60
(1) (2) (3) (4) (5)		
$S_m - R_m - S_g - R_a - S_c$	20%	60%
(1) (2) (3)		
$S_m - R_m - S_r$	80%	40%

In the testing period, when (1) the top button led to (2) a response to the top button, it was followed by (3) a green light, then by (4) the approach response to the tray. This sequence occurred following 100% of the testing responses which were made to the top button, while 100% of those made to the bottom button resulted in only the red light:

Stimulus-response (S-R) chain	Percentage of occurrence following response D-1-20	D-1-60
(1) (2) (3) (4)		
$S_t - R_t - S_g - R_a$	100%	100%
(1) (2) (3)		
$S_b - R_b - S_r$	100%	100%

The percentage of occurrence of the chain associated with the S^r (top) button was closer to the percentage of occurrence of the similar $S_m - R_m - S_g - R_a - S_c$ chain for the D-1-60 group than for the D-1-20 group; the percentage of occurrence of the chain associated with the NS^r button was further from the percentage of occurrence of the similar training chain, $S_m - R_m - S_r$, for the D-1-60 group than for the D-1-20 group. Accordingly, the D-1-60 group would better maintain similarity of training and testing conditions than the D-1-20 group by use of the top button (S^r) and avoidance of the bottom one (NS^r). These results question Saltzman's conclusion that the "alternate" (nondifferential) technique which he used was substantially inferior to the differential technique. The data of the present study suggest that his conclusion was based on the comparison of a weak ND procedure against a strong D-1 procedure.

The trends in the data suggest that the D-2 technique was a less effective one than the D-1, which maximally emphasized the difference between the two test stimuli by pairing one with reward and the other with non-reward. In the testing period, the D-2 groups encountered a novel stimulus whose reinforcing capacity should have served to lessen the difference in number of responses made to the S^r and NS^r buttons. The discrimination was slightly better in the D-2-60 group than in the D-2-20 group, as consideration of the conditions for discrimination would suggest, following from the previous analysis of the S-R relationships in the D-1 group.

The discrimination hypothesis seems to provide a theoretical framework within which a wide variety of data can be integrated. The ability of this approach to explain data with several types of training techniques and with different criteria for the establishment of secondary reinforcement has been previously pointed out (Myers, 1958). The degree to which the results of the present study are compatible with a discrimination hypothesis suggests its potential importance in future theoretical explanations of S^r effects. If the reliability of the trends in the present study can be established, an important step in the development of a theory of S^r effects will have been made.

Discriminative Stimulus Hypothesis

Several authors (Dinsmoor, 1950; Keller & Schoenfeld, 1950; Schoenfeld, Antonitis, & Bersh, 1950) have suggested that a stimulus must be discriminative if it is to become a secondary reinforcer. A discriminative stimulus is one which serves as a cue for the Ss in the experimental situation. Reinforcement is administered when responses are made in its presence, and withheld when they are made in its absence, or in the presence of a negative stimulus. In the differential groups of the present study, the onset of one light during training was the cue for the S to approach the slot tray; this response was reinforced by a candy. Since the approach response was not reinforced in the absence of the PSR, the stimulus was a discriminative stimulus. In the case of the ND groups, the approach response was not consistently reinforced following the onset of the PSR, and therefore was not a discriminative stimulus. However, the results indicate that the nondifferential and differential techniques are comparable in their effects, for a strong S^r effect was found with both procedures. This is consistent with Ratner's (1956) finding that the cue functions of the neutral stimulus were not operative, although a strong S^r effect was obtained.

Reinforcement Schedule

The finding of S^r effects under partial primary reward suggests that the results of studies which have shown little or no differences in effects for such variables as amount of primary reward associated with PSR (Hopkins, 1955; Lawson, 1953), interval between PSR and primary reward presentation (Bersh, 1951; Jenkins, 1950), number of pairings of PSR and primary reward (Bersh, 1951; Hall, 1951a), and drive states (Hall, 1951b), should be questioned. In these experiments, a continuous schedule of primary reward and PSR pairings was generally used during training. If, as seems to be the case, the S^r effect is very weak when it has been established with this procedure, investigations using this technique cannot be expected to evidence strong differences among the treatments investigated. Further investigation of the parameters cited, using partial primary reinforcement during training, seems warranted. In addition, the use of a continuous procedure in an experiment by Miles (1958) suggests that his results are unclear. Miles found that kittens showed a greater preference for an exploratory incentive than for a secondary reinforcer, the food dish which had always been associated with food. While Miles' results are consistent with those of the Control group in the present study, the results of the experimental groups suggest that preferences for the secondary reinforcer can be established if partial primary reinforcement occurs during training.

Suggestions for Further Experimentation

As was pointed out earlier, there was a great amount of within group variability in the present study which may account for the failure to obtain statistically significant differences in discrimination among groups. The operant rates exhibited by the Ss were highly variable, ranging from as few as 5 to as many as 250 and more responses. It is possible that future studies might obtain pre-training operant rates and select Ss on the basis of these. A control of operant rates could be made by employing an experimental design in which groups could be matched for operant rates (Lindquist, 1956, Chapter 5). This approach would have the added advantage of enabling tests of differences in S^r properties as a function of operant rate. Since separate training and testing sessions would be required, a better measure of the persistence of S^r effects would also be obtained.

Another possible source of error variance was the different attitudes of Ss toward candy. Since these Ss were not motivated by any "hunger" drive, the learned attitudes become important. Several of the Ss who preferred to save their candies, would sometimes eat them during the testing period. In studies where there is some uniform and real drive level existent, this situation does not arise. It is difficult to suggest an efficient method of controlling "drive" for these Ss, which would satisfy experimental needs, and not incur the wrath of parents and teachers, but it is possible that other reinforcers would result in less error variance. Brackbill and Jack (1958) found less variability when their Ss were allowed to choose their reward, than when they were arbitrarily reinforced with candy, and Witryol and Fisher (1960) suggest that real differences exist in the value of various reinforcers which have been used with children. If other attractive reinforcers (possibly marbles, money, charms, etc.) could be used, depending on the child's preference, it may be possible to minimize error variance due to differences in motivation.

SUMMARY

The present study was designed to provide: (a) information concerning the establishment and maintenance of secondary reinforcement to establish new stimulus-response relationships in human beings; (b) a more extensive comparison of the differential and nondifferential training procedures used to establish secondary reinforcing properties in a potential secondary reinforcer (PSR); and (c) additional data on the effects of intermittent schedules of primary reinforcer and PSR presentation.

One-hundred and twelve kindergarten children were trained to press a button for a primary reward. Each S was administered one of seven possible combinations of training procedure and percentage of primary reward. Subjects in the Control group were presented the PSR (light) and primary reward (candy) on each of 15 responses. Subjects in the first differential training group were presented the PSR and candy following 15 responses, and presented the non-secondary reinforcer (NS^r) following 10 (for the 60% group) or 60 (for the 20% group) of the remaining responses. Those Ss trained under the second differential technique were presented the PSR and candy following 15 responses, but experienced no experimental change following the remaining 10 or 60 responses. The Ss in the nondifferential training group were presented the PSR after each of their total 25 or 75 responses, but were presented a candy after only 15 of these responses. In the testing period, all Ss discriminated between a button which led to the previous candy-associated light, and one which led to the NS^r light.

The total number of responses made to each button within a 10-minute period was recorded for the testing period. The results indicated that:

1. A significant discrimination can be established in humans under a variety of training procedures and percentages of primary reward.

2. The ND-20 group evidenced greater discrimination than did the ND-60, while the D-1-60 group evidenced greater discrimination than did the D-1-20 group.

3. The D-1 training procedure led to a greater preference for the S^r button than did the D-2 procedure.

4. Those Ss trained with continuous PSR-primary reward pairings evidenced a preference for a novel light rather than for the previously experienced PSR.

The results were discussed in relation to a discrimination hypothesis and to a discriminative stimulus hypothesis. Implications and suggestions for past and future experimentation in secondary reinforcement were made.

REFERENCES

1. Armus, H.L., & Garlich, M.M. Secondary reinforcement strength as a function of primary reinforcement. *J. comp. physiol. Psychol.*, 1961, *54*, 56-58.

2. Beck, R. C. On secondary reinforcement and shock termination. *Psychol. Bull.*, 1961, *58*, 28-45.

3. Bersh, P.J. The influence of two variables upon the establishment of a secondary reinforcer for operant responses. *J. exp. Psychol.*, 1951, *41*, 62-73.

4. Boyle, R.E. Secondary reinforcement and a test of two reinforcement hypotheses concerning the primary reinforcement effect. *J. comp. physiol. Psychol.*, 1961, *54*, 566-571.

5. Brackbill, Y., & Jack, D. Discrimination learning in children as a function of reinforcement value. *Child Develpm.*, 1958, *29*, 185-190.

6. Cowles, J.T. Food tokens as incentives for learning by chimpanzees. *Comp. Psychol. Monogr.*, 1937, *14*, No. 5.

7. D'Amato, M.R., Kachman, R.L., & Kivy, P. Secondary reinforcement as affected by reward schedule and the testing situation. *J. comp. physiol. Psychol.*, 1958, *51*, 737-741.

8. Dinsmoor, J.A. A quantitative comparison of the discriminative and reinforcing functions of a stimulus. *J. exp. Psychol.*, 1950, *40*, 458-472.

9. Dollard, J., & Miller, N. *Personality and Psychotherapy.* New York, McGraw-Hill Co., 1950.

10. Fox, R.E., & King, R.A. The effects of reinforcement scheduling on the strength of a secondary reinforcer. *J. comp. physiol. Psychol.*, 1961, *54*, 266-269.

11. Hall, J.F. Studies in secondary reinforcement: I. Secondary reinforcement as a function of the frequency of primary reinforcement. *J. comp. physiol. Psychol.*, 1951a, *44*, 246-251.

12. Hall, J.F. Studies in secondary reinforcement: II. Secondary reinforcement as a function of the strength of drive during primary reinforcement. *J. comp. physiol. Psychol.*, 1951b, *44*, 462-466.

13. Hopkins, C.O. Effectiveness of secondary reinforcing stimuli as a function of the quantity and quality of food reinforcement. *J. exp. Psychol.*, 1955, *50*, 339-342.

14. Jenkins, W.O. A temporal gradient of derived reinforcement. Amer. J. Psychol., 1950, 63, 237-243.

15. Keller, F., & Schoenfeld, W.N. Principles of Psychology. New York: Appleton-Century-Crofts, 1950.

16. Klein, R.M. Intermittent primary reinforcement as a parameter of secondary reinforcement. J. exp. Psychol., 1959, 58, 423-427.

17. Lawson, R. Amount of primary reward and strength of secondary reward. J. exp. Psychol., 1953, 46, 183-187.

18. Lindquist, E.F. Design and Analysis of Experiments in Psychology and Education. Boston: Houghton-Mifflin, 1956.

19. McGuigan, F.J., & Crockett, F. Evidence that the secondary reinforcing stimulus must be discriminated. J. exp. Psychol., 1958, 55, 184-187.

20. Miles, R. Learning in kittens with manipulatory, exploratory, and food incentives. J. comp. physiol. Psychol., 1958, 51, 39-42.

21. Mowrer, O.H., & Jones, H.M. Habit strength as a function of pattern of reinforcement. J. exp. Psychol., 1945, 35, 293-311.

22. Myers, J.L. Secondary reinforcement: A review of recent experimentation. Psychol. Bull., 1958, 55, 284-301.

23. Ratner, S.C. Reinforcing and discriminative properties of the click in a Skinner box. Psychol. Reports, 1956, 2, 332.

24. Saltzman, I.J. Maze learning in the absence of primary reinforcement: A study of secondary reinforcement. J. comp. physiol. Psychol. 1949, 42, 161-173.

25. Schoenfeld, W.N., Antonitis, J.J., & Bersh, P.J. A preliminary study of training conditions necessary for secondary reinforcement. J. exp. Psychol., 1950, 40, 40-45.

26. Witryol, S.L., & Fisher, W. F., Scaling children's incentives by the method of paired comparisons. Psychol. Reports, 1960, 7, 471-474.

27. Wolfe, J.B. Effectiveness of token rewards for chimpanzees. Comp. Psychol. Monogr., 1936, 12, No. 60.

28. Wyckoff, L.B. Toward a quantitative theory of secondary reinforcement. Psychol. Rev., 1959, 66, 68-78.

29. Zimmerman, D.W. Durable secondary reinforcement: Method and theory. Psychol. Rev., 1957, 64, 373-383.

APPENDIX

Table 5

Total Number of Responses to S^r and NS^r Buttons for Each S in Experimental Groups

Group	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Sum
D-1-20	S^r	89	83	69	23	33	23	136	98	48	108	63	221	40	242	10	176	1462
	NS^r	87	82	72	30	34	5	74	85	56	106	55	0	38	0	258	0	982
D-2-20	S^r	104	231	60	235	97	84	2	104	104	71	159	104	158	31	0	94	1638
	NS^r	166	5	66	0	94	87	118	87	112	69	90	97	58	162	122	96	1429
ND-20	S^r	200	236	180	153	101	38	232	7	104	46	18	206	2	222	36	80	1861
	NS^r	0	0	74	0	0	138	5	86	100	44	28	9	213	6	77	63	843
D-1-60	S^r	11	93	210	230	0	253	41	105	95	71	194	164	189	93	94	18	1861
	NS^r	9	102	0	0	141	0	41	93	3	69	22	0	13	87	98	178	856
D-2-60	S^r	95	71	53	21	115	0	3	4	49	234	219	63	0	8	79	200	1214
	NS^r	92	77	49	23	114	67	204	30	82	1	3	77	50	36	76	0	981
ND-60	S^r	12	26	102	40	268	101	14	129	66	21	175	0	55	1	108	2	1120
	NS^r	8	207	85	0	0	98	14	127	65	40	4	134	34	159	112	101	1188
Control	S^r	106	60	49	50	0	0	2	72	30	105	99	69	110	0	12	21	785
	NS^r	104	60	55	44	277	142	2	66	29	89	97	67	107	171	11	14	1335

Table 6

Schedules for Administration of Primary and Potential Secondary Reinforcement in Training for the 20% and 60% Groups*

20%

S^R __ S^R __ __ __ __ __ S^R __ __ S^R __ __ __ __ S^R __
__ __ __ S^R __ __ __ __ __ __ __ S^R __ __ __ __ __ __
S^R __ __ __ S^R __ __ S^R __ __ __ __ __ __ __ S^R __ __
__ __ __ S^R __ __ __ __ __ S^R __ __ __ __ __ __ __ S^R
__ __ S^R

60%

S^R __ S^R S^R S^R __ S^R S^R __ __ S^R S^R __ S^R S^R __ S^R __
__ S^R __ S^R S^R __ S^R

* S^R represents a response after which primary reward was presented and __ represents a response after which primary reward was not presented. Primary reward never occurred without being preceded by presentation of the PSR, which was presented after each response for the ND groups, and with primary reward for the D-1 and D-2 groups.

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