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The effect of delay of secondary reinforcement in the primary reinforcement delay situation

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THE EFFECT OF DELAY OF SECONDARY
REINFORCEMENT IN THE PRIMARY
REINFORCEMENT DELAY SITUATION

by

Mary Carolyn Bibb Kerfoot

A Thesis

Presented to the Graduate Faculty
of Lehigh University
in Candidacy for the Degree of
Master of Science

Lehigh University

1965

This thesis is accepted and approved in partial fulfillment
of the requirements for the degree of Master of Science.

Sept. 24 1965
(Date)

Arthur L. Brady
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Head of the Department

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ABSTRACT

The present experiment investigated the effect of a temporally delayed secondary reinforcer on learning when primary reward was also delayed. A Grice-type discrimination was used in which albino rats learned to turn to a specific color to receive a dextrose pellet. A familiar food cup, the secondary reinforcer whose delays were tested, appeared 0, 2, or 4 seconds after a correct turn was made. The dextrose tablet was always delivered 4 seconds after a correct response. Each rat received 60 trials.

A type III analysis was employed to test for trend differences among secondary delay groups in this trial by secondary delay by replications design. Although the 3 secondary delay groups did not differ significantly in overall means percent correct response, the slopes of their learning curves did differ at the .05 level. These differences in learning rate indicate that a delayed secondary reinforcer does effect learning in the delay of primary reinforcement situation.

INTRODUCTION

The problem of a temporal gradient of reinforcement has been of theoretical interest since Thorndike's suggestion (1913) that a temporal delay between a response and its effect would retard learning. Delay of reinforcement was considered in more detail by Hull (1932) when he theorized that excitatory potential was a function of temporal or spatial distance from the goal; or in his more formal treatment (1943), that habit strength was dependent upon delay of reinforcement. Wolfe (1934) was the first to demonstrate experimentally the existence of a temporal gradient of reinforcement. His gradient was of an extended nature and showed some learning occurring with reinforcement delays of 10 and 20 minutes. Hull and others believed Wolfe's gradient could be shortened by the elimination of secondary reinforcing factors which were providing reward during the delay period. Perin (1943) investigated the role of secondary reinforcement in the delay of reward situation. He restricted the operation of differential secondary reinforcement by studying a bar pressing response in a single compartment which served as a stimulus situation, delay chamber, and food box all in one. Having reduced secondary reinforcement in this way, the gradient of primary reinforcement which he obtained was considerably shorter than the gradient obtained by Wolfe. In this situation, rats were unable to learn a bar pressing response when primary reinforcement was delayed for 30 seconds. On the basis of this experiment, Hull (1943) reformulated his earlier goal-gradient hypothesis to include the effect of secondary reinforcement. He hypothesized the existence of a short

primary gradient of reinforcement resulting from the elimination of secondary reinforcement, and of the more extended goal-gradient derived from the principle of generalization of secondary reinforcement.

Spence (1947) pursued Hull's analysis to its logical conclusion, denying the existence of any primary gradient of reinforcement. Hull theorized the existence of a short primary gradient when secondary reinforcement was absent; Spence theorized that if secondary reinforcement were entirely eliminated, the primary gradient of reinforcement would collapse to zero. Under such circumstances learning could not occur if the primary reward were delayed. If learning does occur during delay of reinforcement, then secondary reinforcement must be present to provide immediate reward.

Spence's hypothesis has never been explicitly proved due to the difficulty of completely eliminating secondary reinforcing factors from the learning situation. The validity of his hypothesis has been inferred from the results of a number of experiments, each controlling more sources of secondary reinforcement and each obtaining a primary gradient of reinforcement which more nearly approached zero. A large number of secondary reinforcing factors were controlled by Grice (1948) who eliminated differential proprioceptive cues from turning right or left, for example, as well as the usual external cues which might acquire secondary reinforcing properties. His learning task required albino rats to learn a black-white discrimination in which color rather than position was consistently reinforced. He found that rats could not

learn the discrimination when primary reward was delayed for more than 5 seconds. He proposed that if differential visual traces arising from the discrimination were eliminated, the primary gradient of reinforcement would more closely approach zero, as predicted by Spence.

In more recent experiments, manipulation, rather than reduction, of the secondary reinforcement variable has been of interest. An attempt has been made to discover whether a delay of secondary reinforcement gradient exists comparable to the primary delay gradient. Ward (1961) presented rats with food and buzzer pairings on a variable ratio schedule in order to establish the buzzer as a durable secondary reinforcer. He later tested the effects of buzzer delays on the acquisition of a bar pressing response. He found that the buzz was most effective in promoting acquisition of the bar pressing habit when delayed for $\frac{1}{2}$ second after the response. The rats could not learn at all when the buzzer was delayed for 2 seconds. The different effects produced by different buzzer delays seem to demonstrate the existence of a secondary reinforcement gradient similar to the delay of primary reinforcement gradients obtained by Perin and Grice. Apparently this gradient is much shorter than the primary delay gradient. It should be noted that in Ward's experiment, the buzz was never followed by a delayed primary reward. His study dealt with secondary reinforcement delay as an abstract phenomenon, independent of the primary delay situation. The problem of whether a delay of secondary reinforcement gradient will appear in the context of the primary delay experiment remains unanswered as yet. There is a possibility that a secondary delay gradient may not

appear in the context of the primary delay because secondary delay effects are inextricably confounded with differential strength of the secondary reinforcement. That is, those secondary reinforcers which are delayed the longest are closest in time to the delayed primary reinforcement and are thus stronger than those secondary reinforcers which are not delayed as long. The greater strengths of the longer delays may cancel the positive effects of the short delays. Demonstration of this hypothesis may depend on the specific primary and secondary delays used, for if all secondary delays were close enough to, or so far removed from, the primary reinforcement that their relative strengths did not differ, the hypothesis could not be substantiated. On the other hand, it may be that strength of the secondary reinforcer is not as potent a factor in learning as is length of its delay.

It is the purpose of the present experiment to determine whether any differential secondary delay effects may be obtained in the context of the delayed primary reward but not necessarily why differences do or do not exist. The experiment should be so designed that all sources of secondary reinforcement are held constant but one, whose various delays are to be tested. In the original design of this experiment a black-white discrimination was selected in which rats were rewarded for turning left at a T-maze choice point when placed in a black start box, and for turning right from a white start box. This discrimination was chosen since it prevented both differential proprioceptive and visual cues from being consistently associated with reward. This is true because neither position nor color is consistently

rewarded. Rather it is the appropriate combination of position and color which is always reinforced. Other sources of secondary reinforcement such as goal box and doors exposing the food cups would be present for both correct and incorrect responses and so could not be consistently associated with reward. This learning situation seemed to provide the control which was needed over all known sources of secondary reinforcement. Duryea (1955) used such a learning task in his study of response-goal delay versus stimulus-response delay (S-R asynchronism). Smith (1951) seems to have been the only other person to have used this particular discrimination. Smith's experiment investigated delays between the stimulus and response and so is not directly applicable to the delay of reinforcement situation. However, his results, particularly in the zero delay condition, suggest the difficulty of this task for albino rats. Smith ran 10 trials a day for the first 50 days and 20 trials per day thereafter. With an inter-trial interval of not less than 3 minutes, his rats, learned to turn left from a black start box and right from white, under the condition of no delay, after an average of 160 trials. When an approximate delay of .7 seconds was introduced between stimulus and response, albino rats required an average of 900 trials to reach a criterion of 18 correct responses out of 20. Their learning was quite unstable, even under such a short delay, many rats later reverting to position habits. When a 5 second S-R delay was introduced, the rats had not learned after 2100 trials.

Duryea investigated both S-R delay and delay of reinforcement with this learning task. His findings for S-R delay conditions

are widely discrepant from Smith's results. Duryea ran 10 trials per day with a 7 minute intertrial interval. His rats reached a criterion of 18 correct responses out of 20 in an average of 188 trials under an S-R delay of 2 seconds and in 325+ trials under an S-R delay of 4 seconds. Duryea's study seems to be the only one describing the effects of delay of reinforcement in learning such a discrimination. He found that when reward was delayed for 2 seconds after the turning response, albino rats learned this task in a median of 160 trials and in 175 trials when reward was delayed 4 seconds.

A pilot study was conducted to obtain an idea of the difficulty of this task under delay of reinforcement conditions. Primary reinforcement delays of 0, 5, 8, 13 and 17 seconds were tested with this discrimination. None of the rats in any delay condition showed the slightest sign of learning after 95 trials. On the basis of the results of the pilot study and Smith's experiment, the author concluded that turning right or left on the basis of the start box color is an exceedingly difficult task for albino rats to learn, especially when delay of reinforcement is introduced. Therefore, the author decided to test the effect of delay of secondary reinforcement in the primary delay situation by using a simpler learning task.

To ensure learning within a reasonable number of trials a Grice-type discrimination was used in which the rat must always turn to a specific color regardless of whether it required a right or left turn from the start box. The rats were delayed in a delay chamber of the same color as the curtain they had chosen to pass through and ate from

a goal box of the same color. The subjects were divided into three secondary reinforcement delay groups: 0, 2, and 4 seconds. All groups ran under a 4 second primary reinforcement delay. Although this task ensured rapid learning, it did not provide as much control over unwanted sources of secondary reinforcement as did the more complex task. Visual traces from the black-white alleys could take on secondary reinforcing properties since they would be present in the goal box at the time of eating. Nevertheless, the author decided to proceed with this less satisfactory approach rather than abandon altogether the problem of the existence of secondary reinforcement delay effects.

METHOD

Subjects. 24 naive, female, albino rats, approximately six months of age, were used as subjects.

Apparatus. The apparatus which was used is sketched in Figure 1. It was a simple T-maze consisting of a start box (A) and combination stimulus-delay chambers (B and C). Small goal boxes lay just beyond the delay chambers and were separated from the latter by guillotine doors (4 and 5) which hid the food cups. The goal box was just large enough to contain a familiar food cup which was the source of secondary reinforcement whose delays were tested. Start box and delay chambers each measured $15\frac{1}{2}$ " x 5" x 5". The entire maze was painted first gray for preliminary training. Black or white plywood boxes $1/8$ inch thick, were inserted into the delay chambers during the experiment proper. Curtains (wavy lines) the same color as the delay chambers lay just behind guillotine doors 2 and 3, covering the entrances to the delay chambers. In the experiment proper, these curtains were the basis of the black-white discrimination because the rat must turn either right or left to a black or white curtain after the start box door (1) was raised. The curtain selected determined whether a reward was received. The black or white box beyond the curtain was part of the stimulus complex and also served as a delay chamber. Doors 2 and 3 closed behind the rat after a turn was made preventing retracing and confining the animal to the delay chamber. The tops of all maze units were made of plexiglas. Hunter interval timers control the

raising of doors 4 and 5 (that is, length of secondary delay) and delivery of the food reward, (length of primary delay).

Preliminary Training. All rats were placed on a 24-hour food deprivation schedule prior to preliminary training. Food cups, identical to those used later in the experiment, were placed in each cage and the rats were allowed to eat dextrose tablets from their cups. This allowed the food cup to acquire strong reinforcing properties. The rats were also gentled at this time. This procedure was continued for about 2 weeks until all rats ate eagerly from the food cups. Thereafter, 24 rats were divided into 4 squads of 6 rats each. Within each squad, the 6 rats were randomly assigned to the 3 secondary delay groups, each group containing 2 rats. This arrangement of subjects constituted a random replications design with 6 subjects per replication and 2 subjects per experimental group within each replication. The preliminary training described below for the first replication applies to each of the subsequent replications which were run in turn. Throughout the experiment all rats ran under an approximate 20-hour food deprivation schedule. During preliminary training the entire apparatus was a flat gray. On the first day of training, guillotine doors 2, 3, 4 and 5 were open while door 1 was closed. Each rat was placed in the right delay chamber and allowed to run from one chamber to another and eat a maximum of three dextrose pellets from each food cup. If a rat had not eaten a single pellet after 15 minutes, she was removed from the apparatus. On the second day of training, doors 1, 2, and 3 were closed while 4 and 5 were open. Each rat, including those which had

not eaten on the first day, was placed in a delay chamber and allowed to eat one pellet. Ten such trials were given with the order of placement in a delay chamber being LRLRRLRRL. On the third day of preliminary training, each rat was placed in the start box and forced to run to a particular delay chamber by keeping the opposite chamber closed. The order of forced runs was LRLRLRRLR. When the rat entered the delay chamber and approached the food cup, the dextrose pellet was delivered automatically. The click of the mechanism signaled the rats of the pellet's delivery, thus enabling them to eat the pellet as soon as it was delivered. Immediate consumption of the pellet was necessary if exact delay intervals were to be meaningful. The rats which had not learned to eat the pellet as soon as it was delivered were given an additional 14 forced trials in the order LRLLRRLRLRRLR. If a rat still failed to eat immediately, she was replaced by a new rat. After each rat had learned to eat the pellet as soon as it was delivered, she was given two more forced trials, in the order LR, in which doors 4 and 5 were raised automatically, exposing the food cup and pellet after the rat entered the chamber.

Experimental training. In each replication the 6 rats had been randomly assigned to the 0, 2, and 4 second secondary delay conditions. All rats ran under a primary delay of 4 seconds. Three rats in each replication were rewarded for turning to white and three were rewarded for turning to black. Assignment of rats to colors was done on a random basis within each replication. Each rat had her own random sequence of right-left positions in which the correct color was located. The positions of the black and white delay chambers were changed according

to each rat's sequence by shifting the colored plywood inserts and curtains from right to left delay chambers or vica-versa. The rats were run in turn until each had run ten trials per day. Each was given a total of 60 trials. The intertrial interval was approximately 12 minutes. If a rat made a correct response the food cup was exposed after the appropriate secondary delay had elapsed. Regardless of the secondary delay condition, a dextrose pellet was delivered 4 seconds after the correct response was made. If an incorrect response was made, the door (4 or 5) concealing the food cup was never raised and the rat was confined in the delay chamber for a period of 4 seconds. After each trial the rat was placed in a holding cage while the experimenter set the timers and plywood inserts for the next rat. Results of a pilot study indicated that 60 trials was sufficient to allow the rats to reach a level of 90 percent correct responding.

RESULTS

The total of 60 trials was divided into 6 blocks of 10 trials each. Table 1 presents the number of correct responses in each trial block for each rat. Two subjects constitute each replication by secondary delay condition. The mean percent correct responses per trial block for each secondary delay group, collapsed over replications is shown in Figure 2. The exact percentages for the learning curves of Figure 2 are presented in Table 2 along with the overall mean correct percents.

The present experiment may be regarded as a type III design, as discussed by Lindquist (1953) in which a trial by secondary delay conditions design is replicated. A type III analysis was employed to test for trend differences between secondary delay groups. The significance of differences in the overall means and in the slopes of the learning curves was of primary concern in the analysis. Table 3 presents the sum of squares, degrees of freedom, mean squares, and F ratios for the sources of variability in this type III design. The .05 level of significance was employed as the criterion of significance for all F tests. As shown in Table 3, differences in performance from replication to replication proved non-significant as did secondary delay by replication interaction effects. This outcome allowed a meaningful test of the significance of differences in the overall means of secondary delay groups. Although longer secondary reinforcement delays do have an increasingly detrimental effect on black-white discrimination learning, as shown in Table 2, these differences are not significant at the .05 level.

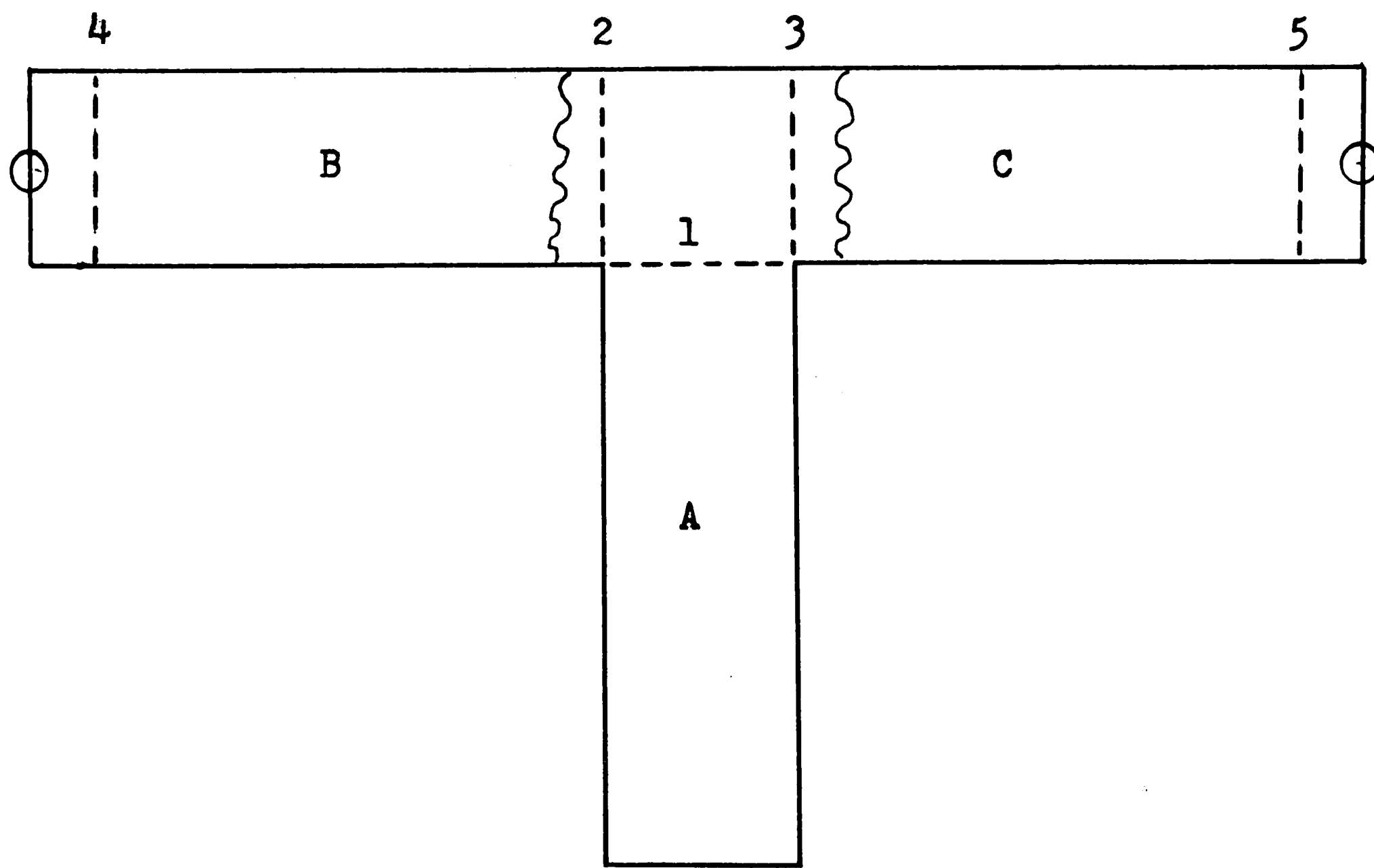


Fig. 1. Diagram of apparatus. See text for explanation.

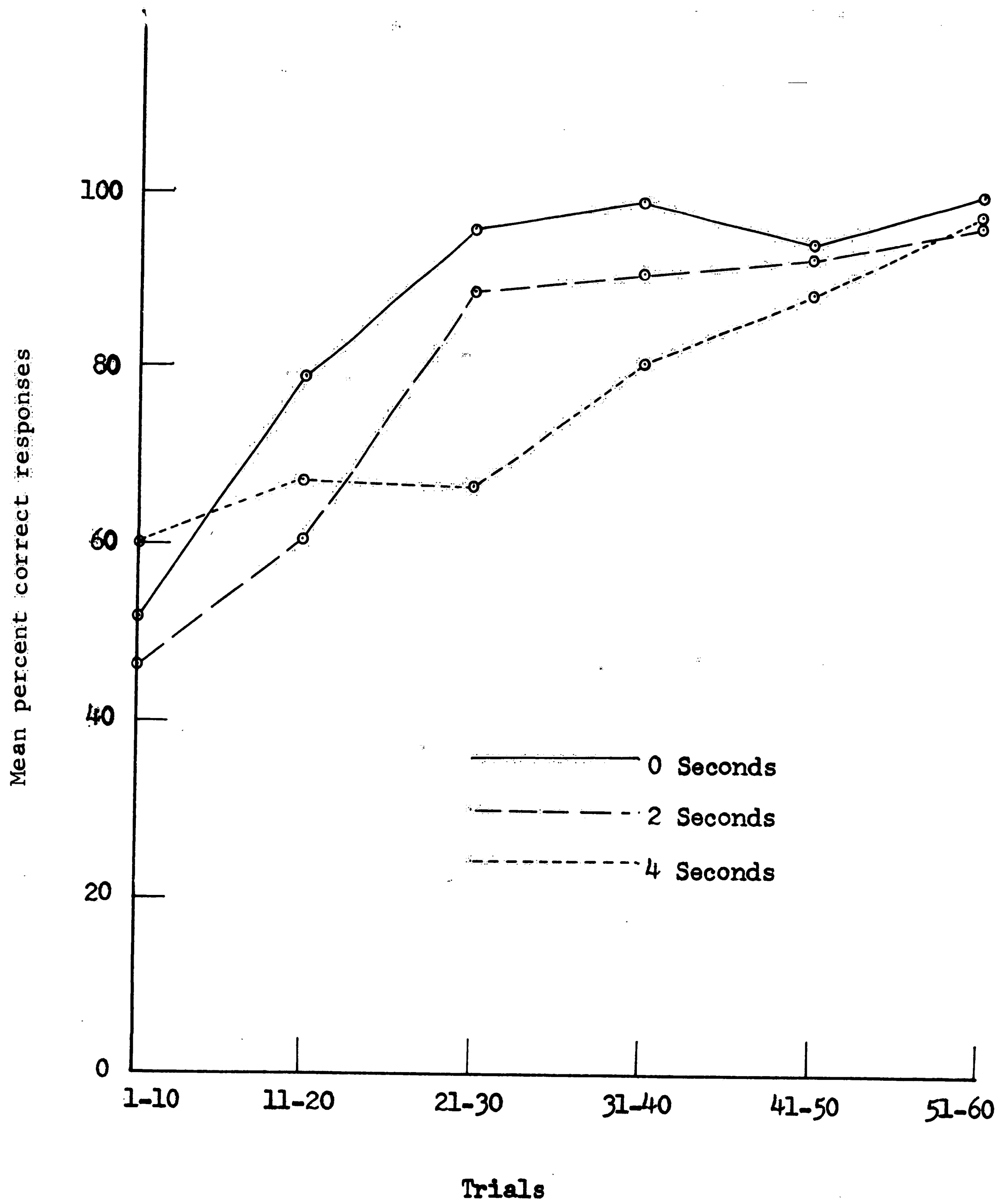


Fig. 2. Mean percent correct responses per block of 10 trials.

Table 1

Number of correct responses per trial block for each of the 24 subjects

| | <u>0 Sec. Delay</u> | | | | | | <u>2 Sec. Delay</u> | | | | | | <u>4 Sec. Delay</u> | | | | | |
|--------|---------------------|----|----|----|----|----|---------------------|---|----|----|----|----|---------------------|---|---|----|----|----|
| | Trial Blocks | | | | | | Trial Blocks | | | | | | Trial Blocks | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| Rep. 1 | 7 | 10 | 10 | 10 | 10 | 10 | 3 | 3 | 7 | 9 | 10 | 10 | 4 | 3 | 7 | 6 | 7 | 8 |
| | 8 | 6 | 10 | 10 | 10 | 10 | 7 | 8 | 10 | 10 | 10 | 10 | 10 | 9 | 8 | 10 | 10 | 10 |
| Rep. 2 | 4 | 8 | 9 | 10 | 10 | 10 | 4 | 8 | 10 | 10 | 10 | 9 | 5 | 6 | 6 | 8 | 9 | 10 |
| | 6 | 10 | 10 | 10 | 9 | 10 | 4 | 5 | 9 | 10 | 10 | 10 | 5 | 6 | 7 | 10 | 9 | 10 |
| Rep. 3 | 3 | 7 | 9 | 10 | 9 | 10 | 3 | 8 | 9 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 10 | 10 |
| | 4 | 9 | 10 | 10 | 9 | 10 | 3 | 5 | 6 | 8 | 10 | 10 | 3 | 5 | 5 | 7 | 8 | 10 |
| Rep. 4 | 3 | 5 | 10 | 9 | 10 | 10 | 7 | 7 | 10 | 9 | 7 | 9 | 5 | 9 | 5 | 9 | 10 | 10 |
| | 6 | 8 | 9 | 10 | 9 | 10 | 6 | 4 | 9 | 7 | 8 | 9 | 7 | 7 | 6 | 6 | 8 | 10 |

TABLE 2

Mean percent correct responses per block of 10 trials.

| | Trial Blocks | | | | | | Overall Mean |
|-----------------|--------------|-------|-------|-------|-------|--------|--------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| 0 Sec. delay | 51.25 | 78.75 | 96.25 | 98.75 | 95.00 | 100.00 | 86.67 |
| 2 Sec. delay | 46.25 | 60.00 | 87.50 | 91.25 | 93.75 | 96.25 | 79.17 |
| 4 Sec. delay | 60.00 | 67.50 | 66.25 | 81.25 | 88.75 | 97.50 | 76.88 |

TABLE 3

Analysis of variance of correct responses.

| Source | SS | df | MS | F |
|---------------------------------------|--------|-----|-------|--------|
| Between Subjects | 134.66 | 23 | | |
| Secondary delay cond. | 25.18 | 2 | 12.59 | 1.54 |
| Replications | 5.41 | 3 | 1.80 | < 1 |
| Secondary delay x Replications | 5.99 | 6 | 1.00 | < 1 |
| Error (b) | 98.08 | 12 | 8.17 | |
| Within Subjects | 553.17 | 120 | | |
| Trials | 353.95 | 5 | 70.80 | 52.06* |
| Trials x sec. delay | 49.57 | 10 | 4.96 | 3.65* |
| Trials x replications | 26.63 | 15 | 1.78 | 1.31 |
| Trials x sec. delay x replications | 41.60 | 30 | 1.39 | 1.02 |
| Error (w) | 81.42 | 60 | 1.36 | |
| Total | 687.83 | 143 | | |

*Significant at .05 level.

The trials effect was highly significant, while interactions involving replications, namely, trials by replications and trials by secondary delay by replications, were non-significant. Differences in the slopes of the learning curves (that is, trials by secondary delay interaction) were significant.

Because the learning curves proved significantly non-parallel, pair-wise differences in slopes were tested for significance. Mean square ratios were computed separately for each of the 3 pairs of curves. Error (w) computed from the data as a whole was used as the error term. Table 4 presents the sum of squares, degrees of freedom, mean squares, and F ratios for the 3 pairs of slope differences. As the table shows, the difference in slope between the 0 second and 2 second secondary delay groups was non-significant while differences between the 0 second and 4 second and between the 2 second and 4 second delay groups were significant.

TABLE 4

Analyses of variance for pair-wise differences in slopes
of learning curves

| Source | SS | df | ms | F |
|---|-------|----|------|-------|
| Trials x sec. delay for 0 and 2 sec. group | 7.50 | 10 | .75 | < 1 |
| Trials x sec. delay for 0 and 4 sec. group | 35.18 | 10 | 3.52 | 2.59* |
| Trials x sec. delay for 2 and 4 sec. group | 31.68 | 10 | 3.17 | 2.33* |
| Error (w) | 81.42 | 60 | 1.36 | |

DISCUSSION

It would appear from the experimental results that differential effects of delay of secondary reinforcement do exist in the delay of primary reinforcement situation. As Table 2 indicates, differences can be found in the overall mean percent correct responses. This is particularly noticeable on trials 21-30 as seen in Figure 2. Such differences may arise as change occurrences since they were not significant at the .05 level. On the other hand, large individual differences in maze ability may have prevented differences in secondary delay effects from attaining significance.

Differences in adjustment to the apparatus may be one source of individual differences operating above the influence of secondary delay conditions. The author observed casually that those rats which ate readily and were not alarmed by the automatic operation of the doors and food delivery mechanism generally learned most rapidly. Another source of individual differences is the difference in ability of each rat to utilize cues other than the food cup as immediate sources of secondary reinforcement.

An additional factor operating against the detection of significant differences in overall means was that the response levels of the 3 secondary delay groups were nearly equivalent at the beginning and the end of the acquisition series. This was true because the forced trials during preliminary training were designed to have each

subject start the experiment with a 50-50 chance of making a correct response. Furthermore, 60 acquisition trials allowed each group to reach an asymptote of nearly 100percent correct responding. There was, therefore, little opportunity for differences in overall means to be found significant.

Strong support for the existence of differential secondary delay effects is the significant difference in learning rate between secondary delay groups. The 0 and 2 second delay groups appeared to learn in the typical, negatively-accelerated manner while the performance of the 4 second delay group remained depressed for several trial blocks and then rose directly to what would be its asymptote. The fact that differences in learning rate appeared even though there were several sources of secondary reinforcement present to provide immediate reward indicates that the food cup must have possessed very potent reinforcing properties. Elimination of these other sources of immediate reward may accentuate differences in overall mean performance as well as reduce large individual differences due to differences in ability to utilize these immediate cues.

The hypothesis that a delay of secondary reinforcement gradient exists in the primary delay experiment can neither be supported nor denied by the present experiment because the primary and secondary delay intervals were too short to cause different response asymptotes from group to group. Experimentation with longer delays should provide an answer to this problem.

SUMMARY

A number of experiments have demonstrated the effects of delay of primary reward upon learning in the white rat. Interest has arisen concerning the effect of a delayed secondary reinforcer upon learning. A study by Ward indicated that a delay of secondary reinforcement gradient exists in the situation in which reward is never available. The present study investigated the effect of delay of secondary reinforcement in the learning situation in which the primary reward was not only available but delayed. A Grice-type discrimination was used in which female, albino rats were rewarded for turning to a specific color regardless of whether it was located to the right or left of the start box. The rats were delayed in a delay chamber of the same color as the curtain to which they turned and ate from a goal box of the same color. A familiar food cup was the source of secondary reinforcement and was revealed to the rat either 0, 2, or 4 seconds after she had chosen the correct color. All rats ran under a primary (dextrose pellet) delay of 4 seconds. Each rat received 60 trials. A type III analysis was used to test for trend differences among secondary delay groups in this trial by secondary delay by replications design. Although the 3 secondary delay groups did not differ significantly in overall mean percent correct responses, the slopes of their learning curves did differ at the .05 level. The 0 and 2 second secondary delay curves both differed significantly from the 4 second delay curve. These differences in learning rate indicate that delay of

secondary reinforcement does effect learning when primary reward is also delayed. Indications of an actual dealy of secondary reinforcement gradient are not available from this experiment since all groups eventually reached a 90 percent correct response level. Longer delays and more complete elimination of immediate sources of reward may produce different response asymptotes and differences in overall mean percent correct response.

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VITA

Mary Carolyn Bibb Kerfoot, daughter of Robert and Rachel Bibb, was born in Ottumwa, Iowa, on January 1, 1942.

A 1960 graduate of Ottumwa Senior High School, she attended the State University of Iowa from 1960 to 1962. In August, 1962 she married Robert Kerfoot and continued her studies at Muhlenberg College during 1963. She graduated from the State University of Iowa in August 1963 with a major in Psychology and a minor in Mathematics.

In September 1963 she began her graduate work at Lehigh University in the department of Psychology. She was a graduate assistant in the University Counseling and Testing Service under Robert Panos from July 1964 to June 1965.