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ABSTRACT

Investigates the effect of delay of reinforcement upon human discrimination learning with particular emphasis on the form of the gradient within the first few seconds of delay. In previous studies subjects are usually required to make an instrumental response to a stimulus, this is followed by the delay interval, and finally, the reinforcement occurs. The present procedure did not require any instrumental response during the experimental treatment. Instead, a pair of stimuli was presented for a brief period, a delay interval occured, and then a light appeared over the stimulus that the subject was instructed to remember. In the present situation the subject is required to associate a stimulus with the reinforcement light. Classical conditioning literature indicates that an interstimulus interval of about .50 sec. produces optimal conditioning. Even small changes in either direction from this interval produce performance decrements. Thus, evidence from both animal discrimination learning and classical conditioning support the importance of the first second or two of the interval between the occurrence of two stimuli that are to become associated. In this series of experiments, particular attention was given to delay intervals between 0 and 2.0 sec. with other delays ranging up to 5.0 sec. (Author/RC)

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Research with infra-human organisms has shown that learning is facilitated when a response is followed in close temporal contiguity by reinforcement. Reviews of this research (e.g., Spence, 1956; Mowrer, 1960; Kimble, 1961) also indicate that immediate reinforcement is preferred to delayed, and the effectiveness of reinforcement decreases with increasing delay. Determining the existence of a delay of reinforcement gradient and its physical shape has been an important problem for some time. A series of investigations (e.g., Wolf, 1930; Perin, 1943; Perkins, 1947), culminating in a rigorously controlled study by Grice (1948), indicated that the delay gradient for animals is quite steep. Learning was found to be markedly retarded when reinforcement was delayed for only 1.0 sec. and virtually eliminated when delayed for 5.0 sec. The effect of delay of reinforcement upon human discrimination learning is much less certain. Either the delay gradient has not been obtained (e.g., Erikson & Lipsitt, 1960; Brackbill & Kappy, 1962; Brackbill, Bravos, & Starr, 1962) or appeared only with delay intervals considerably in excess of Grice's 5.0 sec. (e.g., Hockman & Lipsitt, 1961).

At the present time there is little evidence concerning the effects of very short reinforcement delays upon human learning in general and discrimination learning in particular. Of the few experiments that have sought to investigate the effecta of the first few seconds of delay (e.g., Noble & Alcock, 1958; Hetherington, Ross, & Pick, 1965; Dokecki, 1964), none have yielded positive results. Perhaps delays of reinforcement of less than about 10.0 sec. have no detrimental effects on human discrimination learning.

The purpose of the current series of experiments was to investigate the effect of delay of reinforcement upon human discrimination learning with particular emphasis on the form of the gradient within the first few seconds of delay. In previous studies Ss are usually required to make an instrumental response to a stimulus, this is followed by the delay interval, and finally, the reinforcement occurs. The present procedure did not require any instrumental response during the experimental treatment. Instead, a pair of stimuli was presented for a brief period, a delay interval occurred, and then a light appeared over the stimulus that the S was instructed to remember. This procedure is similar to the one that occurs in classical conditioning where the conditioned stimulus is to be associated with the unconditioned stimulus. In the present situation the S is required to associate a stimulus with the reincorcement

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light. A review of the classical conditioning literature (e.g., Kimble, 1961) indicates that an interstimulus interval of about .50 sec. produces optimal conditioning. Even small changes in either direction from this interval produce performance decrements. Thus, evidence from both animal discrimination learning (e.g., Grice, 1948) and classical conditioning (e.g., Kimble, 1961) support the importance of the first second or two of the interval between the occurrence of two stimuli that are to become associated. In this series of experiments, particular attention was given to delay intervals between 0 and 2.0 sec. with other delays ranging up to 5.0 sec.

Experiment I

Method

Subjects. The Ss were 80 ninth through twelfth-grade students from a state boarding school for dependent children (Tennessee Preparatory School) in Nashville, Tennessee. There were 31 girls and 49 boys ranging in age from 14.1 to 20.7 with a mean age of 16.4 years. Only students with IQ scores above 85 on the verbal scale of a previously administered Lorge-Thorndike Intelligence Test were selected for participation. The IQ's of the Ss ranged from 87 to 113 with a mean of 102.2.

Twenty Ss were randomly assigned to each of four groups in a simple randomized design employing four levels of delay of reinforcement (0, 0.5, 1.0, and 5.0 sec.). An analysis of variance indicated that there were no significant differences between the IQ's of the experimental groups.

Apparatus. The discrimination apparatus was a 14 in. by 19 in. oblique metal box that was mounted on a table 30 in. high. Planometric stimuli were exposed on two 1 in. circular stimulus windows by two small projectors (Grason-Stadler-10N83). The stimulus windows were located 3 1/3 in. apart and 3 in. from the bottom of the sloping front of the box. Each projector could combine one of eight geometric forms with one of four color backgrounds yielding a pool of 32 possible stimulus compounds. The forms were a large (3/4 in.) and a small (1/4 in.) square, triangle, circle, and crescent. The colors were red, green, blue, and light grey. A push-button response switch was mounted 1 in. below each stimulus window, and the green reinforcement light was a lamp located 1/2 in. above each window. The electro-mechanical relay equipment that controlled the stimulus presentations and recorded the S's responses was located in a room adjoining the test cubicle. Industrial timers (Grason-Stadler-E 4430) were used to determine all temporal intervals. Kymograph and Veeder Root counters monitored the S's responses.

Procedure. Eight pairs of stimuli were selected from the stimulus pool with one member of each pair arbitrarily designated as correct. Three random orders of presentation of the eight stimulus pairs were used, and a Gellerman series was used to randomize the position of the correct stimulus member of each pair. The correct and incorrect stimulus members in one order of presentation are listed below:

	Correct	Incorrect
1.	Small green circle	Large red triangle
2.	Small red circle	Small blue circle
3.	Small green square	Small red crescent
4.	Small blue crescent	Small blue crescent
5.	Small red square	Small green crescent
6.	Large grey crescent	Small blue triangle
7.	Large blue square	Small green triangle
8.	Large green square	Large red square

In this experiment, delay intervals of 0, 0.5, 1.0, and 5.0 sec. were used with a different group of Ss in each condition. The learning task was divided into a pretraining and a testing phase. In pretraining a stimulus array was presented for 2.0 sec. and then removed. After the appropriate delay interval, the correct member of the pair was reinforced with the green light. The S was required to observe the presentation of the stimuli and to associate the green light with the correct member. The S was seated in front of the discrimination apparatus by E and given these pretraining instructions:

> This is a learning task and it comes in two parts. These are your instructions for the first part. Notice these two windows (E points), and these two green lamps (E points). Pairs of pictures will appear in the windows. One member of each pair is correct, and is to be remembered. The other member is incorrect. You will know which picture is correct, because the green lamp above it will light up. This is what will happen. A pair of pictures will come on, and stay on long enough for you to get a good look at them. They will then go off. A short time later the lamp above the correct picture in the pair will come on. Your job is to learn the picture in each pair that always gets the green light. You will get to see each pair a number of times to give you a chance to learn the correct pictures. Do your best to learn, because in the second part you will push one of these buttons (E points), the button under the picture that is correct in each pair. Ready? I will tell you when this part is over.

After these instructions were read and it was determined that S understood the task, E left the test cubicle and started the presentations. The Ss were allowed to see each of the eight stimulus pairs three times. After pretraining, E again entered the cubicle and read these instructions for the testing phase:

> This is the second part of the task. The pictures will come on just as before. This time you push the button under the picture that is correct in each pair. If you are right, the light will come on above the picture immediately. If not, nothing will happen, but the next set of pictures will come up. Keep pushing until you can get all of the correct pictures. Push only once for each pair, because

if you push twice your score will be erased and you must get so many in a row correct to finish. Ready? I will let you know when you are through.

In pretraining the presentation time for each pair of stimuli was 2.0 sec., the interval between termination of the reinforcement light for one pair and the presentation of the next pair was held constant at 6.0 sec. for all groups.

The maximum duration of a single presentation was 2.0 sec. in the testing phase. If S responded before the end of this interval, the presentation was terminated immediately. If S did not respond while the stimuli were visible, he responded in their absence. The next pair could not appear until a response had been made to the previous pair. An 8.0 sec. interval elapsed between S's response and the presentation of the next pair. In all cases the duration of the reinforcement light was 2.0 sec.

The criterion of learning was two errorless trials, i.e., 16 successive correct choices. If the S did not reach this criterion in 36 trials, he was stopped, but his score was included in the data for that group. Seven out of 80 Ss failed to reach criterion.

Results

The dependent variable was number of correct responses per trial for each subject. The mean number of correct responses per pair and the standard deviations for each group are presented in Table 1. The graphic presentation of these data in Figure 1 shows that the highest and lowest means were obtained by the 0.5 sec. Group and the 1.0 sec. Group respectively.

TABLE 1

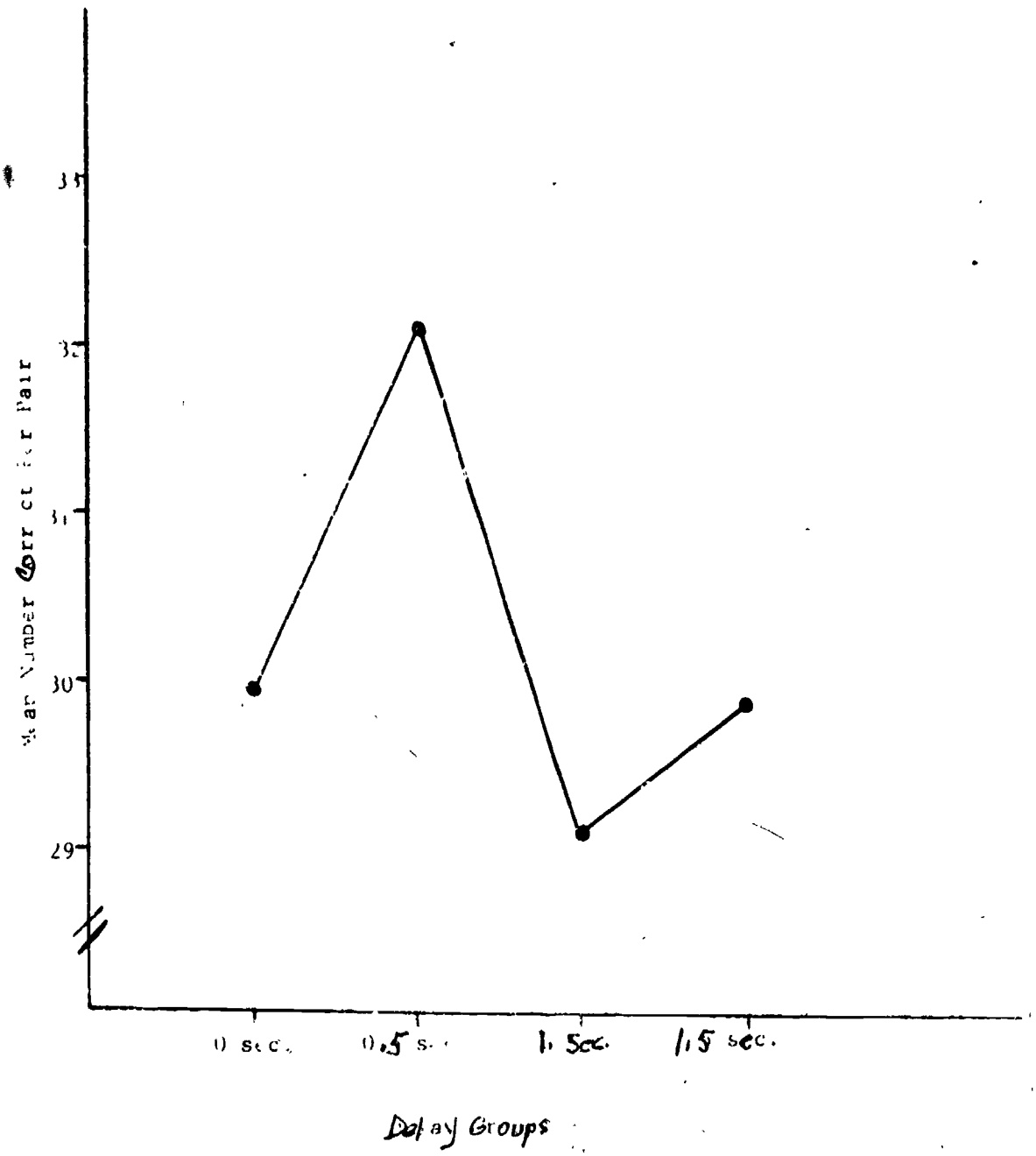
Means and Standard Deviations: Experiment I

Group	0 sec.	0.5 sec.	1.0 sec.	5.0 sec.
Mean	29.95	32.11	29.09	29.86
S.D.	4.95	2.20	4.15	4.26

The data were combined into four blocks of nine trials each and an analysis of variance was performed. Although the differences between the means in Figure 1 appear relatively large, the main effect of Groups was not statistically significant, $F(3,76)=1.94, p < .25$. Since the intersubject variability was quite great, any real differences that might exist between these conditions could have been obscured. The Trials effect was significant, $F(3,228)=186.82$, $p<.001$ indicating that learning occurred over the four trial blocks.

Figure 1

Mean Number of Correct Responses Per Pair
for Each Group in Experiment I



Experiment II

This experiment was conducted to determine whether the findings of Experiment I could be replicated and to institute some slight procedural changes.

Method

Subjects. The Ss were 120 college students enrolled in undergraduate psychology courses. The 85 women and 35 men ranged in age from 18 to 38 years with a mean of 20.7 years. Twenty Ss were randomly assigned to each of five experimental groups and one control group.

Apparatus. The equipment and materials for Experiment II were the same as for Experiment I with the following exceptions: (a) Eight new stimulus pairs were selected from a pool made up of combinations of seven forms and five color backgrounds. The forms were: a row of three 3/16 in. white circles positioned either vertically, horizontally, or at a 45 degree angle, an upright and an inverted 1/2 in. triangle, and straight white lines alternating with a colored background and positioned either vertically or horizontally. The colors were: red, green, blue, yellow, and light grey. (b) The industrial timer previously used to determine the delay of reinforcement intervals, was replaced with a more accurate electronic timer (Grason-Stadler-E5350A).

Procedure. The correct and incorrect stimulus members in the first of three random orders of presentation appear below.

	Correct	Incorrect
1.	Horizontal blue lines	Angled red circles
2.	Upright green triangle	Horizontal grey circles
3.	Horizontal yellow lines	Inverted red triangle
4	Vertical blue circles	Upright yellow triangle
5.	Horizontal red lines	Vertical grey lines
6.	Inverted grey triangle	Upright blue triangle
7.	Horizontal yellow circles	Horizontal green lines
8.	Angled green circles	Vertical yellow circles

The task in Experiment II also was divided into a pretraining and a testing phase. There were five reinforcement groups and a control group in the experimental design. The control group, which was presented with the stimulus pairs, but no reinforcement light, was added to determine the relative extent of learning in the reinforcement groups during the pretraining phase. A contiguous reinforcement group that was presented the stimulus pairs and reinforcement simultaneously also was added. The four remaining groups received delays of reinforcement of either 0, 0.5, 1.0, or 3.0 sec. during pretraining. Both the stimulus pairs and the reinforcing stimulus remained on for an interval of 2.0 sec. There was an interval of 6.0 sec. between the termination of the reinforcement light for the preceding stimulus and the presentation of the next pair for all groups except the control group which simply had a 6.0 sec.

interval between stimulus pairs.

The testing phase in Experiment II was similar to that of Experiment I except that the stimuli could remain on for a maximum interval of 10.0 sec. If the S responded before this, the presentation was terminated immediately. Only rarely did a S require more than 10.0 sec. to make a choice. A response was necessary, however, before the next pair could appear. There was an 8.0 sec. interval between the S's response and the presentation of the next pair of stimuli. The duration of the reinforcement light was 2.0 sec.

All Ss in this experiment, except those in the control group, were given pretraining and testing instructions similar to those in Experiment I. It was emphasized, however, that the task was simply to try to memorize which of the two pictures in each pair was correct. For pretraining of the control group, the instructions were simply to sit and observe pairs of pictures which would serve as discrimination problems in the second part of the task. For testing of the control group the full pretraining and testing phase instructions were given.

The criterion of learning was two successive errorless trials. If a S failed to reach this criterion in 30 trials, he was stopped, but his score was included in the data of his group. Six out of 120 Ss failed to reach the criterion of learning.

Results

The mean number of correct responses per pair and the standard deviations for each group are presented in Table 2. Although the shape of the curve in Experiment II differs somewhat from that in Experiment I, it may be seen in Figure 2 that the 1.0 sec. Group again obtained the lowest mean among all delay groups.

TABLE 2

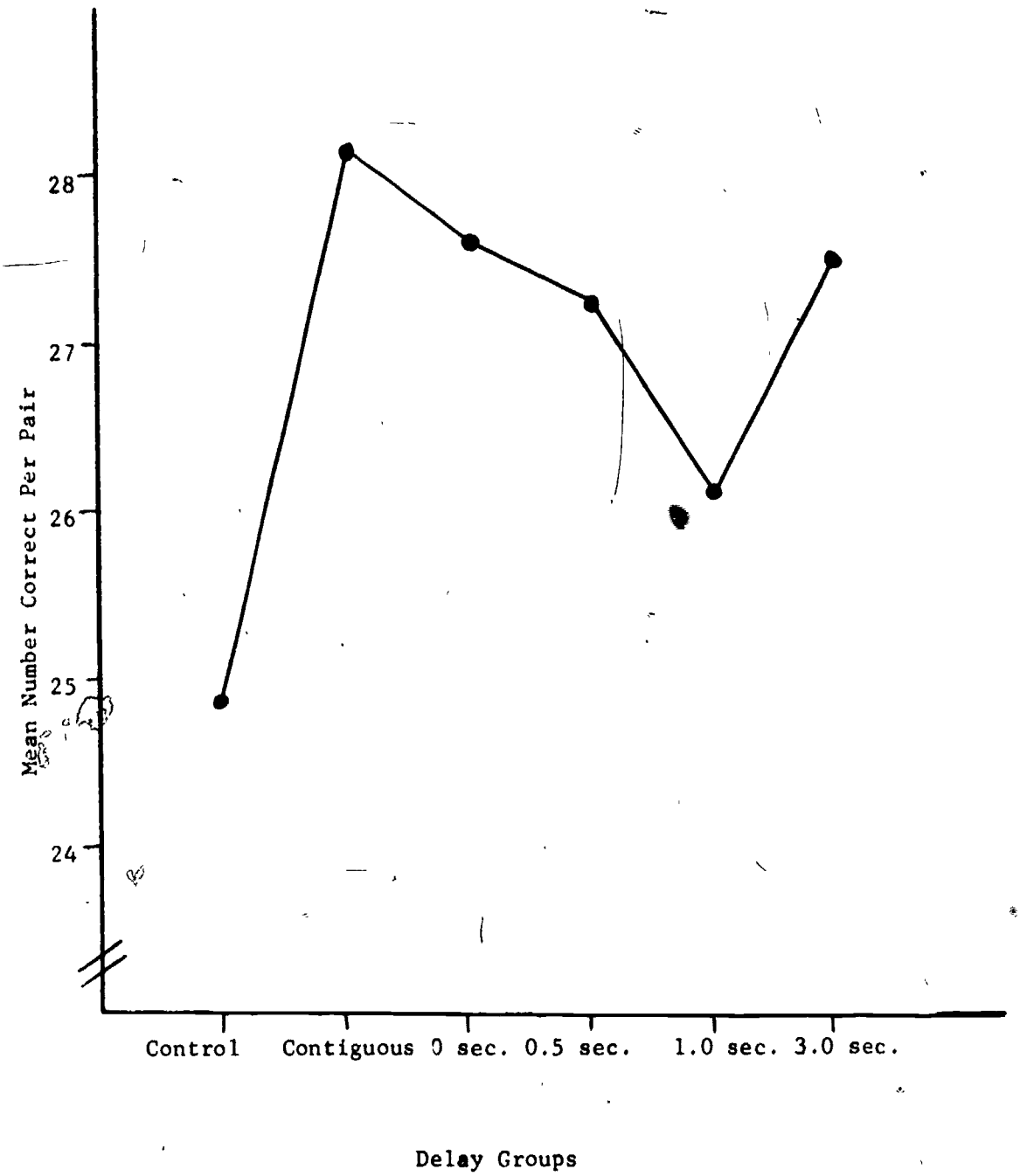
Means and Standard Deviations: Experiment II

Group	Control	Contiguous	0 sec.	0.5 sec.	1.0 sec.	3.0 sec.
Mean	24.89	28.18	27.60	27.27	26.11	27.53
S.D.	3.09	1.85	2.20	1.74	3.18	3.03

These data were combined into five blocks of six trials each and an analysis of variance was performed. All effects in this analysis were highly significant. The Groups effect, $F(5,114)=3.80$, $p<.005$, indicates that there were differences among the means of the six groups; the Trials effect, $F(4,456)=202.20$, $p<.005$, indicates that learning occurred on the task; and the Groups X Trials interaction $F(20,456)=3.77$, $p<.005$, suggests

Figure 2

Mean Number of Correct Responses Per Pair
for Each Group in Experiment II



that there were differential rates of learning among the groups. The differences among the group means were tested with the lsd (least significant difference) test (Federer, 1955, p. 70), which is a variation of the multiple t test. The results showed that the mean of the Control Group was significantly different ($p < .01$) from the means of all other groups except the 1.0 sec. Group. These differences were expected since the Control Group presumably had no opportunity to learn the discriminations during pretraining. However, the lack of difference between the Control Group and the 1.0 sec. Group suggests that the 1.0 sec. Group learned little during pretraining either. The only other significant difference was between the means of the 1 0 sec. Group and the Contiguous Group.

Experiment III

In Experiment I and Experiment II a 1 0 sec. delay of reinforcement appeared to have a detrimental effect on learning. Although the results lacked overall statistical significance, there were relatively large mean differences between groups. In order to reduce the influence of individual subject differences across delay conditions a within subjects design was used in Experiment III.

Six stimulus pairs, six subject groups, and six delay of reinforcement intervals (0, 0.5, 1.0, 1.5, 2.0, and 3.0 sec.) were assigned to the columns, rows, and cells, respectively, of a 6 x 6 Latin square. Every S within a group received six stimulus pairs with each pair having a different delay of reinforcement interval. The assignment of delay interval to stimulus pairs was systematically alternated across S groups so that all stimulus pairs were learned under all delay conditions.

Method

Subjects. Introductory psychology students were randomly assigned to six groups of 3 Ss each for a total of 18 Ss. The 12 females and six males ranged in age from 18 to 25 years with a mean age of 19 2 years.

Apparatus. The apparatus and materials differed from those in Experiments I and II as follows: (a) Hunter timers replaced previously used devices to time delay intervals; (b) six new stimulus pairs were selected from a pool made up of combinations of six forms and four color backgrounds. The forms were: a large (3/4 in.) and a small (1/4 in.) triangle, square and crescent. The colors were: red, blue, green, and grey.

Procedure. As before, the presentation order of the stimulus pairs and the position of the correct pair member were randomized within three unique six-trial blocks. The correct and incorrect stimulus members in their first order of presentation are listed below:

	Correct	Incorrect
1.	Small green crescent	Large blue triangle
2.	Large red square	Large green crescent
3.	Small green triangle	Small blue square
4.	Large grey triangle	Large green square
5.	Large blue crescent	Small grey triangle
6.	Small blue square	Small red crescent

The task in Experiment III was similar to that in Experiment's I and II. In pretraining both the stimulus pairs and the reinforcement lights remained on for 2.0 sec. The interval between cermination of reinforcement light and presentation of the next pair was held constant at 4.0 sec. Each subject received four pretraining trials (i.e., four presentations of each of the six stimulus pairs with its assigned delay interval).

The testing phase in this experiment was the same as that in Experiment's I and II. Maximum duration of stimulus presentation was 5.0 sec., reinforcement was presented for 2.0 sec., and reinforcement to next stimulus interval was 4.0 sec.

The instructions for Experiment III were the same as those in Experiment II. The criterion of learning was two successive errorless trials. If an S failed to reach this criterion in 24 trials, he was stopped, but his score was included for analysis.

Results

The dependent variable in this experiment was total number of correct responses per pair for each subject. The mean number of correct responses and the standard deviations for each delay interval are shown in Table 3. The means for each condition are presented graphically in Figure 3 where it may be seen that a performance decrement occurred in the 1.5 sec. condition.

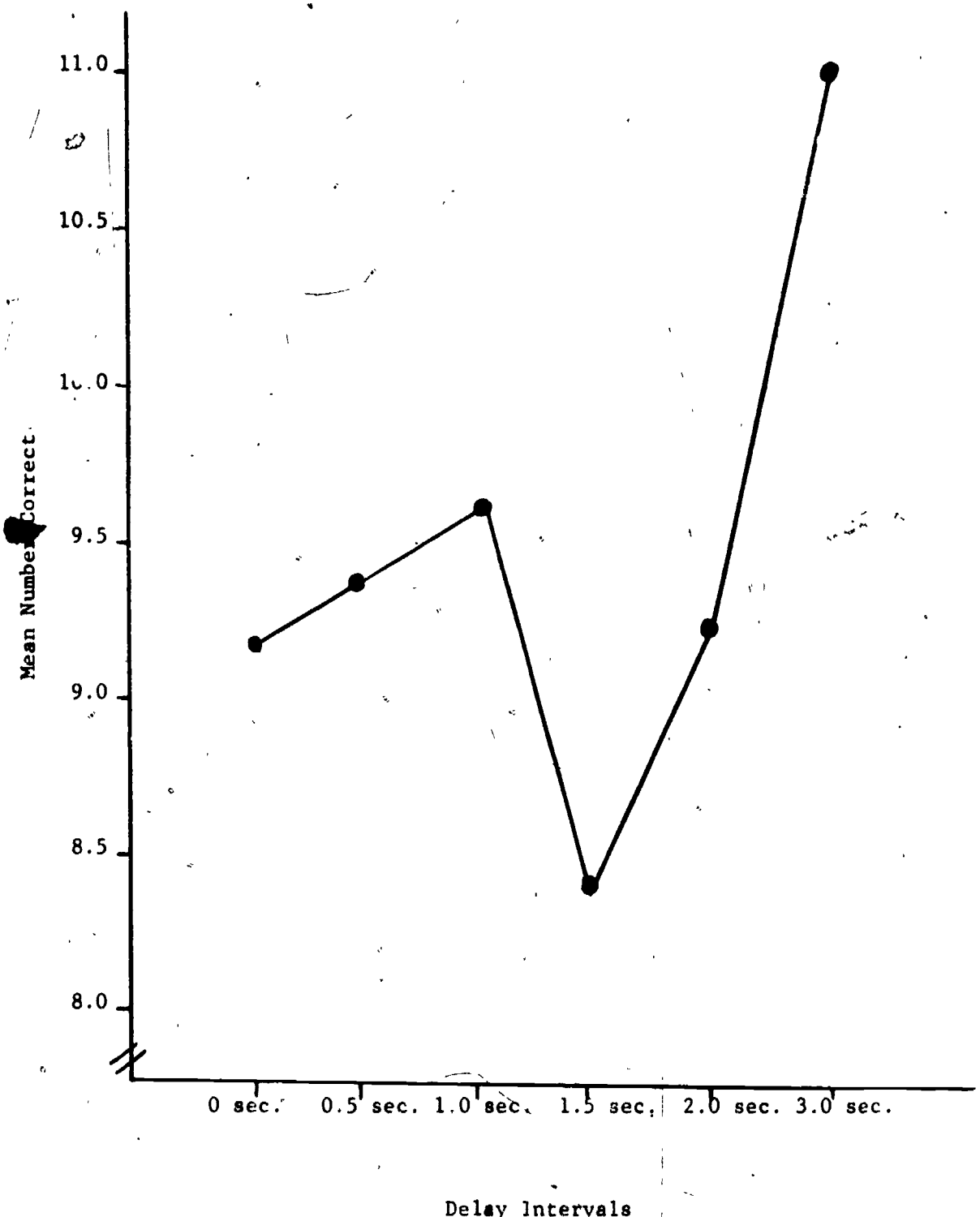
TABLE 3

Means and Standard Deviations: Experiment III

Interval	0 sec.	0.5 sec.	1.0 sec.	1.5 sec.	2.0 sec.	3.0 sec.
Mean	9.17	9.39	9.61	8.39	9.22	11.00
S.D.	5.76	5.10	5.30	5.78	5.46	6.75

Figure 3

Mean Number of Correct Responses for Each Condition in Experiment III



A Lindquist (1953) Type II analysis of variance was performed on the data. The Intervals effect, $F(5,60)=2.24$, $p < .10$, indicated that there were no significant differences among the means for the six intervals. Both the Pairs effect, $F(5,60)=3.47$, $p < .01$, and the Pairs X Intervals interaction, $F(20,60)=2.99$, $p < .001$, were significant indicating that the individual pairs varied in learning difficulty and that the difficulty of a particular pair varied across delay intervals.

The results of this experiment differed slightly from those of Experiments I and II where the performance decrement occurred in the 1.0 sec. condition. However, the curvilinear shape of the delay gradient remained the same in all three experiments. It would appear that there may be an interval rather than a point within the first 3.0 to 5.0 sec. of the temporal continuum where delay is disruptive. This interval seems to be between 1.0 and 1.5 sec.

Experiment IV

Experiment IV incorporated changes in procedure with the intention of increasing treatment effects and further testing the reliability and generality of the performance retardation phenomenon previously observed.

Method

Subjects. Eighteen undergraduate psychology students were randomly assigned in equal numbers to six groups. The four males and 14 females ranged in age from 18 to 21 years with a mean age of 18.9 years.

Apparatus. Identical with Experiment III

Procedure. The design of the experiment remained the same as in Experiment III, and only minor changes in the procedure were made. In pretraining the number of presentations of each of the six stimulus pairs was increased from four to six and the duration of each presentation was increased from 2.0 to 3.0 sec. The reinforcement to next stimulus interval was increased from 4.0 to 8.0 sec., while the duration of reinforcement was reduced from 2.0 to 1.0 sec. In all other respects the procedures of Experiments III and IV were identical. Delay of reinforcement of either 0,0.5, 1.0, 1.5, 2.0, or 3.0 sec. was associated with a particular stimulus pair for a given subject. Reassignment of delay intervals to stimulus pairs was made over subject groups.

Results

The mean number of correct responses and the standard deviations for each delay interval are presented in Table 4. Inspection of this table indicates that only small differences occurred between delay conditions, the means ranging from a low of 7.39 at 3.0 sec. delay to a high of 8.05 at 0.5 sec. This lack of differences is evident in the essentially flat shape of the delay gradient plotted in Figure 4.

Figure 4

Mean Number of Correct Responses for
Each Condition in Experiment IV

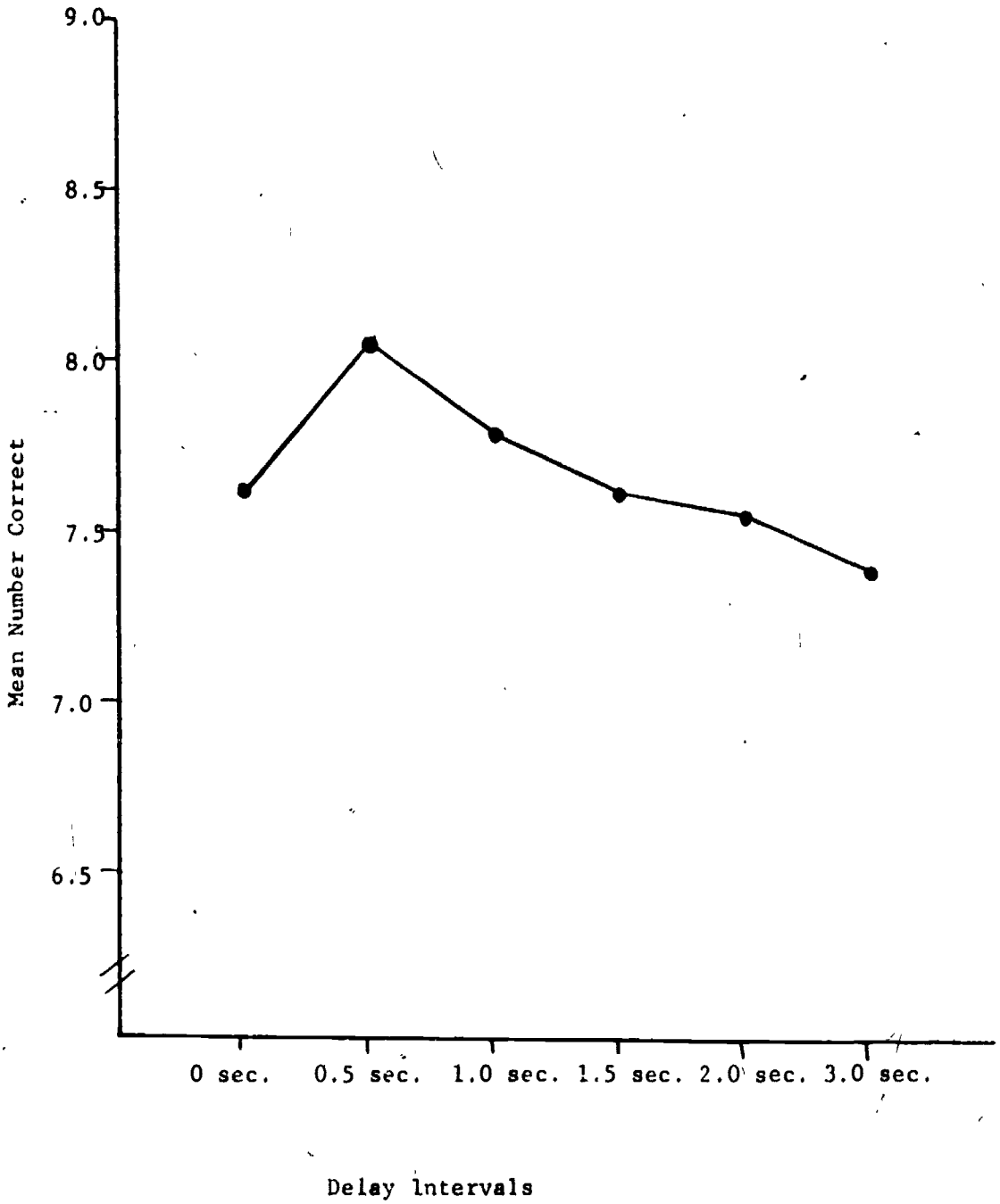


TABLE 4

Means and Standard Deviations: Experiment IV

Interval	0 sec.	0.5 sec.	1.0 sec.	1.5 sec.	2.0 sec.	3.0 sec.
Mean	7.61	8.05	7 78	7.61	7.55	7.39
S.D.	4.83	4.93	4.82	4.38	5.17	4.80

A Lindquist (1953) Type II analysis of variance was performed on the data, but the main effect of Interval was not significant, $F(5,60)=.27$, $p > .05$. However, the Pairs effect and the Pairs X Interval interaction were significant $F(5,60)=4.18$, $p < .005$; $F(20,60)=2.06$, $p < .05$, respectively. Again, it appears that unequal and inconsistent pair difficulty may have obscured differences between delay of reinforcement conditions. It should be pointed out that the testing procedure also may have minimized the chances of obtaining significant delay effects. During testing all correct responses were reinforced with 0 sec. delay and learning carried out to a rather strict criterion. If delays of reinforcement did differentially affect learning rate in pretraining, the requirement that all responses in testing be immediately reinforced would seem to equalize the differences upon which the analysis depends.

Experiment V

It was observed that inconsistent pair difficulty and immediate reward testing procedures might have contributed to the reduction of delay group differences. New stimulus pairs and a study, test procedure were employed in this experiment in an attempt to solve these problems.

Method

Subjects. Twenty-four undergraduate psychology students were assigned at random to six equal groups. There were 19 females and 5 males ranging in age from 17 to 35 years with a mean age of 20.7 years.

Apparatus. The apparatus remained unchanged from Experiment IV except that a green lamp was installed between and 2 inches above the reinforcements lamps on the S's response panel. This lamp remained off during a study trial, but lit up to indicate a test trial. The list of stimulus pairs was taken from the stimulus pool described in Experiment III.

Procedure. Attempts were made to reduce inequality in stimulus pair difficulty by deleting those cues which elicited extremes in response in Experiments III and IV. The six stimulus pairs finally selected in their first order of presentation appear below:

	Correct	Incorrect
1.	Large grey triangle	Large green crescent
2.	Small green triangle	Small grey square
3.	Small green crescent	Large blue triangle
4.	Large blue crescent	Large green square
5.	Small blue square	Small grey crescent
6.	Large grey square	Small blue triangle

At the end of Experiment IV the objection was raised that testing with immediate reinforcement might have equalized the very differences that delays of reinforcement were intended to produce. In an attempt to correct this problem and increase the influence of experimental treatments a study, test procedure was utilized. A study trial consisted of one presentation of each of the six stimulus pairs together with its assigned delay interval. Immediately following a study trial a test trial was given which also called for one presentation of each stimulus pair. This time the S was required to choose that member of the pair which was reinforced on the previous trial, but he received no reinforcement for doing so. The instructions read to each subject are presented below:

> This is a learning task and it is divided into a series of study period-test period sessions. A study period will go like this: A pair of different pictures will appear in these windows (point), and then they will go off. One member of that pair is correct and is to be learned and remembered. The other member is incorrect. You will know which picture is the correct one, because a short while after the pair is turned off, one of these blue lamps (point) will light up. The one that was over the correct picture in that pair. The study period will contain a number of different pairs of pictures and you are to try to learn the correct picture in each pair and the blue lamp tells you which one it is. You are to do nothing during a study period but try to remember the picture in each pair that gets the blue light.
>
> A test period will begin when this green lamp in the middle (point) lights up. This will tell you that when the next pair appears you are to push one of these buttons (point) onethat is under the correct picture in that pair. The pairs that appear in the test session are the same ones you just saw in the study session. At first you will probably not remember which is the correct picture to push the button for, but after a number of study periods in which the same pairs will always appear, you will begin to learn. Do your best to remember the correct pictures in each testing session so that you will be able to complete the task. You are to push only once for each pair during testing, and a testing session is only when the green lamp is lit up. Any questions?

The study, test sequence was repeated ten times. This procedure allowed the continuous measurement of learning under differential delay of reinforcement without the equalizing effects of immediate reinforcement while the dependent measure was taken.

Individual stimulus pairs were associated with either 0, 0.5, 1.0, 1.5, 2.0, or 3.0 sec. delay of reinforcement. Stimulus presentation and reinforcement to stimulus intervals were held constant during a study trial at 2.0 and 4.0 sec. respectively. The duration of the reinforcement light was 1.0 sec. Stimuli were presented for a maximum of 2.0 sec. during a test trial.

Results

The mean number of correct responses and the standard deviations for each delay interval are presented in Table 5. Inspection of Figure 5 shows that again there was an apparent retardation in performance at delay intervals of 1.0 and 1.5 sec. These results are in general agreement with those of Experiments I, II, and III where a curvilinear delay gradient also was obtained.

TABLE 5

Means and Standard Deviations: Experiment V

Interval	0 sec.	0.5 sec.	1.0 sec.	1.5 sec.	2.0 sec.	3.0 sec.
Mean	6.46	6.50	5.87	5.83	6.33	6.37
S.D.	2.10	2.22	2.10	1.65	1.88	1.79

A Lindquist Type II analysis of variance of the data yielded a significant Pairs effect, $F(5,90)=8.32$, $p < .001$, and a significant Pairs X Interval interaction, $F(20,90)=4.16$, $p < .001$. Again, the main effect of Interval was nonsignificant, $F(5,90)=1.34$, $p > .10$.

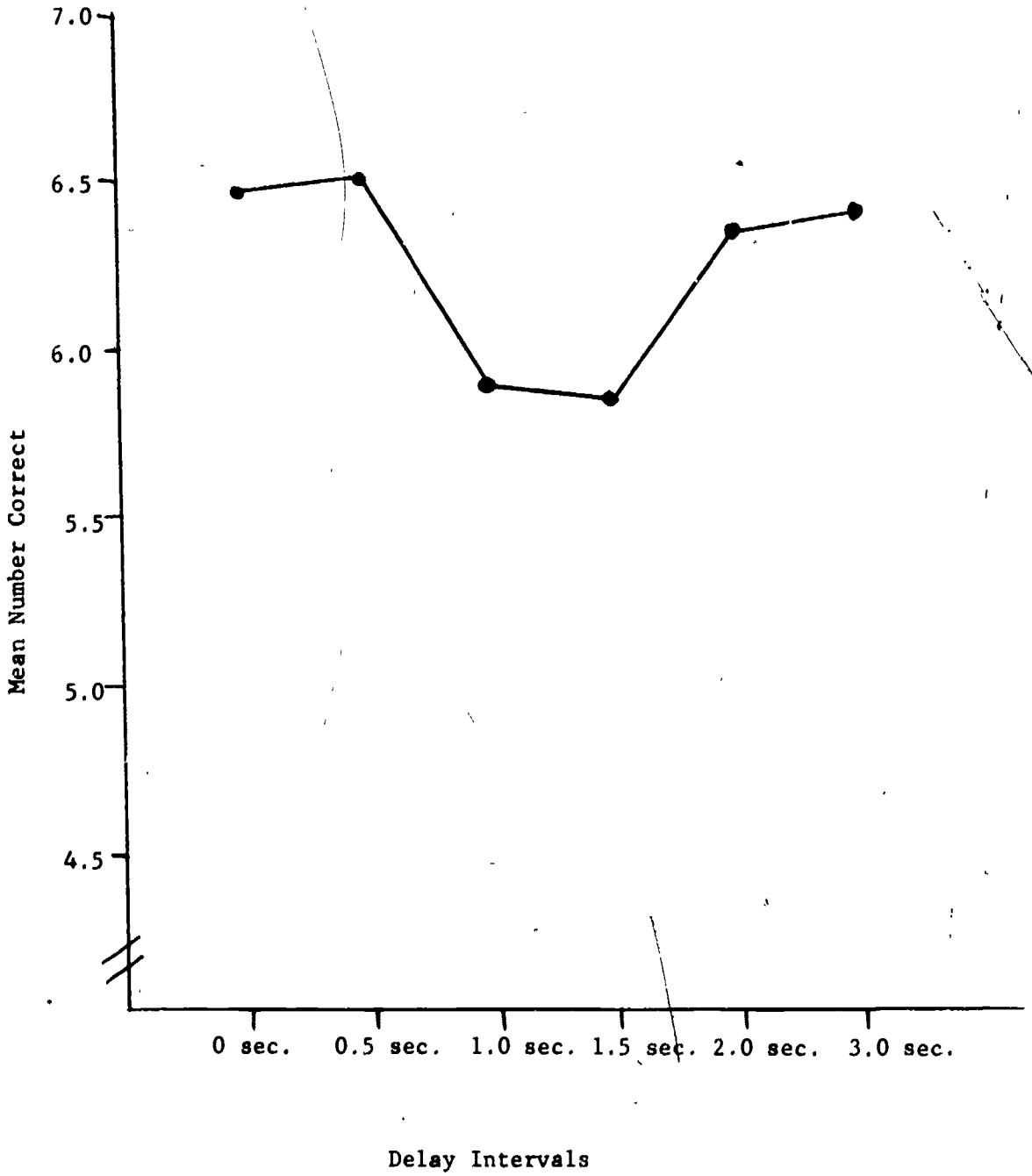
The results of this experiment seem to indicate that discrimination learning may be adversely affected by delays of reinforcement within an interval of from 1.0 to 1.5 sec. Intervals either shorter or longer (up to 5.0 sec.) seem more conducive to learning.

Discussion

Although the main effect of delay in Experiment I was not statistically significant, inspection of mean plots and learning curves suggested that the 0.5 sec. delay interval may have been an optimal condition for learning. The literature on both human and animal discrimination learning generally indicates that immediate reinforcement produces the most rapid acquistion. The present findings partially contradict the typical results which show that as reinforcement is delayed, a decrement in performance occurs. It

Figure 5

Mean Number of Correct Responses for Each Condition in Experiment V



should be noted that the procedure used in this study was analogous to the classical conditioning paradigm. The S must learn to associate a stimulus picture (conditioned stimulus) with a reinforcement light (unconditioned stimulus). In reviewing the literature, Kimble (1961) found best classical conditioning at a CS-US interval of about 0.5 sec., and poorer conditioning with either longer or shorter intervals.

If the effect of the 0.5 sec. delay interval in Experiment I was real, then it would closely parallel the effect of the 0.5 sec. interstimulus interval in classical conditioning. A second experiment was conducted to test the reliability of the phenomenon, but failed to replicate the results obtained in Experiment I. In Experiment II contiguous reinforcement seemed to produce the best performance. This result agrees with earlier findings (e.g., Hockman & Lipsitt, 1961; Terrell & Ware, 1961; and Ware & Terrell, 1961). Any explanation of the disappearance of the 0.5 sec. effect could only be conjecture. The phenomenon appeared only as a trend in Experiment I, and any of the changes in procedure in Experiment II could have produced its disappearance.

The most powerful and reliable effect in Experiments I and II involved the 1.0 sec. delay interval. In both experiments this condition retarded the learning rate. Performance was poorest in the 1.0 sec. delay interval while performance improved with intervals either shorter or longer.

In Experiment III a delay of 1.5 sec. appeared to produce the most interference with learning. While these results appeared to disagree with those of Experiments I and II, it is to be noted that the curvilinear shape of the delay gradient remained essentially the same. It was hypothesized that there exists an interval between about 1.0 and 1.5 sec. where delay of reinforcement has a disruptive effect. Delays of either shorter or longer duration (up to about 5.0 sec.) appear to be more conducive to learning. The results of Experiment V gave support to this hypothesis; performance was better with delay intervals either shorter or longer than 1.0 or 1.5 sec.

In order to account for these rather atypical results, a two process mechanism was used, combining Hulls'(1952) concept of the stimulus trace and the notion of verbal mediation.

Hull (1952) postulated that after "a brief stimulus impinges upon a suitable receptor there is initiated the recruitment phase of a self-propagating molar efferent trace impulse...." (p. 5). Further, that the trace reaches a maximum strength .45 sec. after stimulus onset and then gradually dissipates. The stimuli in this experiment were presented for 2.0 sec. The trace generated presumably reached a maximum strength and was maintained until stimulus offset. The Contiguous and 0 sec. conditions provided a situation in which the trace was at maximal strength, thus the association between the correct stimulus and the reinforcement light should have been facilitated equally in both conditions. In the 0.5 sec. condition, the stimulus trace presumably decreased in intensity, but probably not to a degree that affected performance on this task. The data indicated that these three conditions produced similar results. Data from Reynolds (1945)

and Kimble (1947) suggest that an interval of 1.0 sec. or greater causes an appreciable dissipation of the stimulus trace. The relative decrease in performance in the 1.0 and 1.5 sec. conditions of the present research supports the Reynolds and Kimble interpretation. Presumably the stimulus trace is strong enough to maintain performance in the 0 and 0.5 conditions, but becomes ineffectual about 1.0 sec. after stimulus offset.

An entirely different concept is required to explain the increase in performance that occurs with delay intervals of 2.0 to 5.0 sec. The stimulus trace hypothesis predicts a decrease in learning with an increase in delay. It is suggested here that human Ss are able to overcome the deleterious effects of prolonged delays by producing verbal labels for the stimuli and using those labels to mediate the delay interval. Brackbill and Kappy (1962) used the notion of verbal mediators to explain their failure to obtain a delay gradient with intervals of 0, 5.0, and 10.0 sec. These authors theorized that human Ss can produce and use certain response originating cues. If the experimental task and procedure are of such a nature as to permit the Ss to use these cues, then the delay decrement will be decreased by virtue of a bridging or mediation effect. Brackbill and Kappy felt that since their stimuli were familiar, easily named objects, Ss were able to use verbal rehearsal and self-stimulation to mediate the delay interval. In the present research common geometrical objects on colored backgrounds served as the stimuli. It is presumed that these stimuli were easily named, and that the Ss were able to use these verbal labels as mediators during the longer delay intervals. This is one possible explanation of the relatively high performance of the 2.0, 3.0, and 5.0 sec. delay groups. The role of the 1.0 to 1.5 sec. delay interval in this discussion is far from clear. Apparently the stimulus trace does not support performance after about 0.5 sec. delay, and it takes longer than 1.5 sec. for rehearsing with verbal mediators to become effective. The 1.0 to 1.5 sec. delay interval appears to be a kind of middle ground: too long for the stimulus trace, yet not long enough for verbal mediators to have an effect. This may account for the fact that the delay gradient is frequently obtained with animal Ss, but only rarely with humans. During the delay interval, the animal subject presumably must depend on a fading stimulus trace and any secondary reinforcers present in order to learn. The human, on the other hand, is capable of rehearsing with verbal labels and thus is able to mediate rather long delay intervals.

Experiment VI

Hull's concept of the stimulus trace was applied in a two process interpretation of the curvilinear shaped delay gradient obtained in the present research. According to Hull, neural trace impulses reach maximum intensity 0.5 sec. after initial stimulation and then decline. Therefore, a reduction of the pair presentation interval from 2.0 to 0.5 sec. should not affect the strength of the trace impulse. However, by shortening the pair presentation interval, the likelihood that an S will be able to verbalize the stimuli should be reduced. If stimulus verbalization fails to occur, the delay gradient should be only under the influence of the stimulus trace. The gradient should remain relatively

flat until the trace deteriorates to a point no longer efficient for learning. Increasing delays should cause it to decline and reversals of the trend, presumably due to verbal mediating processes, would not be expected. The purpose of Experiment VI was to determine if such relationships exist. If they do, the two-processes theory here ascribed to would gain support.

Method

Subjects. Thirty undergraduate psychology students were randomly divided into six groups of five Ss each. The seven males and 23 females ranged in age from 18 to 44 years with a mean age of 22.4 years.

Apparatus. Same as in Experiment V.

Procedure. Basically, the procedure was the same as that in Experiment V. The stimulus presentation interval was reduced, however, from 2.0 to 0.5 sec., while the number of study, test presentations was increased to 15. Delay intervals of 0, 1.0, 1.5, 2.0, 3.0, and 4.5 sec. were employed. Instructions remained the same except that it was emphasized that only six pairs were to be learned.

Results

Table 6 contains the mean number of correct responses and the standard deviations for each delay interval.

TABLE 6

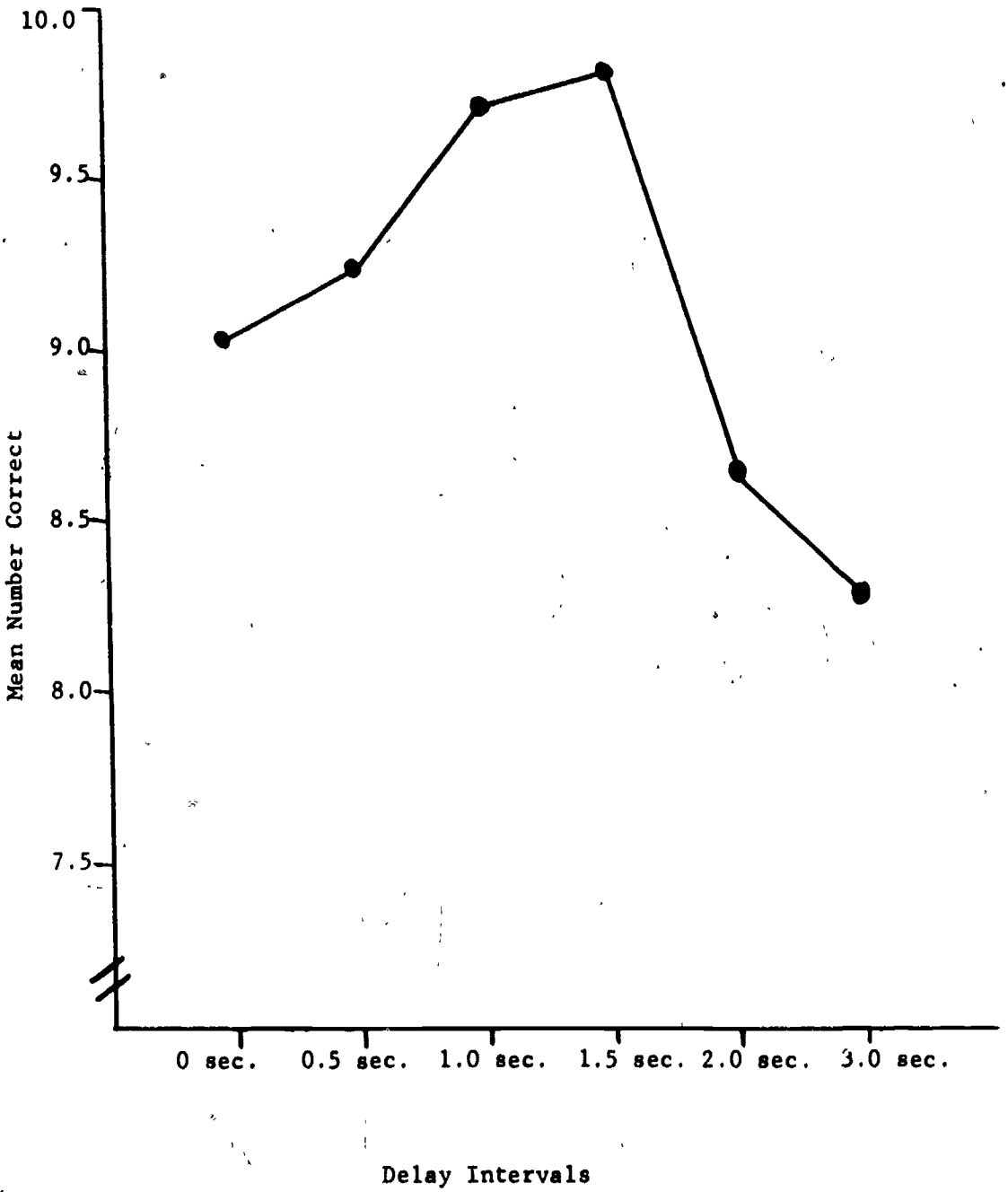
Means and Standard Deviations: Experiment VI

Interval	0 sec.	1.0 sec.	1.5 sec.	2.0 sec.	3.0 sec.	4.5 sec.
Mean	9.03	9.23	9.70	9.80	8.63	8.27
S.D.	2.94	2.99	2.88	2.76	3.41	2.66

A Lindquist Type II analysis of variance was performed on the data yielding a nonsignificant main effect of Intervals, $F(5, 120) = 2.04$, $p < .10$. The Pairs X Intervals interaction again was significant, $F(20, 120) = 2.27$, $p < .005$. Inspection of the delay gradient in Figure 6 shows a trend for more efficient learning with intervals of 2.0 sec. or less and a depression at delays of 3.0 and 4.5 sec. This trend is inconsistent with those obtained in Experiments I, II, III, and V where a performance decrement occurred at intervals of 1.0 or 1.5 sec. In the present experiment, performance did not decline until delay was increased to 3.0 sec. It appears that the stimulus presentation interval may be a critical factor in determining the location on the delay gradient where

Figure 6

Mean Number of Correct Responses for Each Condition in Experiment VI



a performance decrement appears. It should be noted that once learning efficiency began to decline, the trend was not reversed. This supports the prediction that shortening the stimulus presentation time would have a deleterious effect on the Ss verbal mediating behavior.

Experiment VII

In Experiment VI reduction of the stimulus presentation interval to 0.5 sec. appeared to eliminate the facilitation effect presumed to be due to stimulus verbalization. A final experiment was conducted to check the reliability of these results.

Method

Subjects. Twenty-seven undergraduate psychology students were randomly assigned to three groups of nine Ss each. The mean age of the group was 18.6 years.

Apparatus. No change from Experiment VI.

Procedure. The procedure and design of this experiment remained the same as Experiment VI with the following exceptions: (a) two stimulus pairs were associated with one of three delay intervals: 0, 2.5 or 5.0 sec.; (b) stimulus presentation time was 1.0 sec.

Results

Correct response score means and standard deviations are contained in Table 7. Since the average difference between the means was so small, an analysis of variance was not performed. The delay gradient plotted in Figure 7 manifests a gradual downward trend with increasing delays, but differences are too slight to be considered meaningful or interpretable.

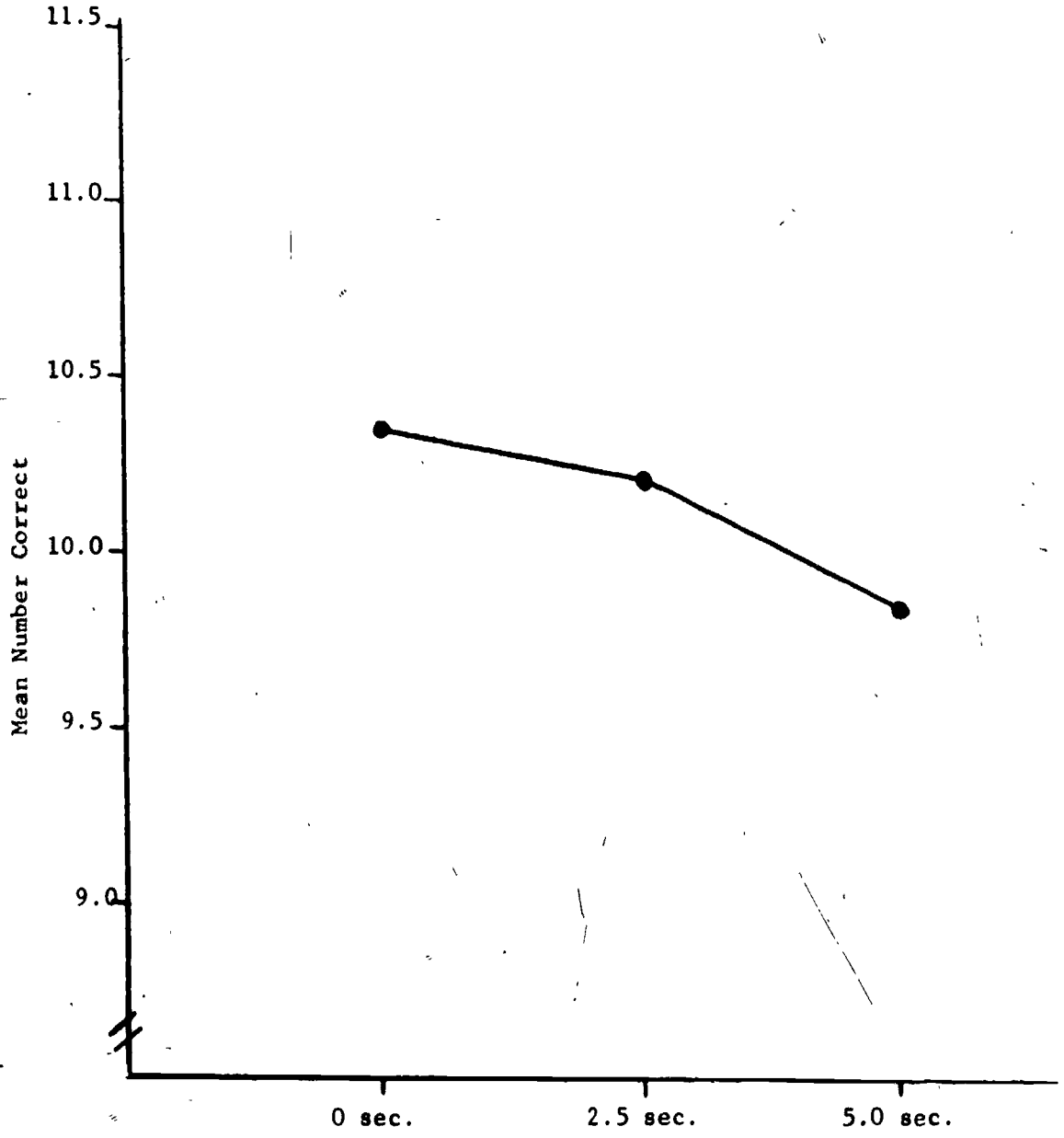
TABLE 7

Means and Standard Deviations: Experiment VII

Interval	0 sec.	2.5 sec.	5.0 sec.
Mean	10.35	10.20	9.83
S.D.	2.48	2.31	2.79

Figure 7

Mean Number of Correct Responses for
Each Condition in Experiment VII



Summary

The typical delay of reinforcement gradient frequently obtained in animal learning (e.g., Perin, 1943; Perkins, 1947; Grice, 1948) was not found in the present research. It may be that delay intervals of less than 5.0 sec. simply do not produce an orderly decrement in human discrimination learning. Past evidence supplied by Noble and Alcock (1958), Hetherington, Ross, & Pick (1965), and Dokecki (1964) suggests that this is the case.

The current series of experiments have yielded some relatively consistent trends in the shape of short term delay gradients which bear consideration.

The stimuli for two-choice discriminations were presented for 2.0 sec. in Experiments I, II, III, and V. Following termination of stimulus presentation, delays of reinforcement of up to 5.0 sec. ensued. After the delay, reinforcement was given the correct member of a pair, and the S was instructed to learn these pair members. Reinforcement delays either shorter or longer than about 1.0 or 1.5 sec. resulted in a higher rate of learning. In order to account for the curvilinear shape of the delay gradient a two process interpretation was invoked, calling for the interaction of Hull's stimulus trace concept and human verbal mediating behavior.

It was suggested that human Ss are able to mediate delay of reinforcement intervals of less than about 1.0 or 1.5 sec. on the basis of stimulus trace. Beyond this interval the trace deteriorates to a degree no longer adequate to serve as a delay mediator and performance declines. Performance improves again when the S has time to rehearse with verbalized stimuli. This apparently occurs with delays longer than 2.0 sec.

In Experiment VI stimulus presentation time was reduced to 0.5 sec. to determine if shortening this interval would reduce the S's presumed verbalizations. It was intended that performance be only under the influence of the stimulus trace. The prediction was made that performance would be poorer at delays of 1.0 or 1.5 sec. and that no increase in performance would occur with longer intervals. The second prediction was confirmed, but performance was not poorer until the delay interval was increased to 3.0 sec. It appears that the duration of stimulus presentation also may have been a critical factor in determining the relative effects of delay of reinforcement on performance. Further research is required to clarify this complex of temporal relationships.

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