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Proactive Inhibition In Pigeon Short-term Memory

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PROACTIVE INHIBITION IN PIGEON SHORT-TERM MEMORY

by

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ABSTRACT

Five experiments were performed, using a delayed matching-to-sample (DMTS) procedure, to investigate the effect of prior learning upon the retention of subsequent learning in pigeon short-term memory. Two basic conditions were employed. In the Experimental Condition, 2 DMTS trials, T1 and T2, were presented in immediate succession. Correct and incorrect colors on T1 were reversed on T2. In the Control Condition, T1 was not presented and T2 occurred in isolation. The comparison of interest was the percentage of correct T2 responses as a function of delay in the 2 conditions. In Exp. I, it was found that (a) presenting T1 1 or 6 times before T2 increased the rate at which T2 was forgotten over the first 6-sec. of the 10-sec. retention intervel relative to the Control Condition (proactive inhibition (PI) effect), (b) presenting T1 4 times before T2 produced a PI effect over the first 2-sec. of the retention interval, (c) presenting T1 1 or 6 times resulted in better T2 retention at the 10-sec. delay than at the 6-sec. delay, and (d) increasing the number of times T1 was presented, from 1 to 6, resulted in a relatively constant increase in the amount of interference across T2 delays. In Exp. II, it was found that T1 did not interfere with T2 retention if neither the correct nor the incorrect color on T1 appeared on T2. In Exp. III, it was found that a prior complete DMTS trial constituted a more potent source of interference than did various components of a DMTS trial. In Exps. IV and V, it was found that (a) separating the termination of a single T1 presentation from the onset of T2 by either 20 or 40 sec. completely eliminated the PI effect and (b) when T1 was presented twice, separating the termination of the second T1

presentation from the onset of T2 by 20 sec. reduced the magnitude of the PI effect and a separation of 40 sec. eliminated the PI effect. Although several theoretical interpretations of the results are possible, it was concluded that the Grant and Roberts' model may provide the most adequate interpretation. The model holds that interference effects are the product of competition between conflicting memories at retrieval; the degree of competition being a joint function of the degree of overlap between the trace strength distributions of the 2 conflicting memories and of the animal's ability to discriminate the most recent memory.

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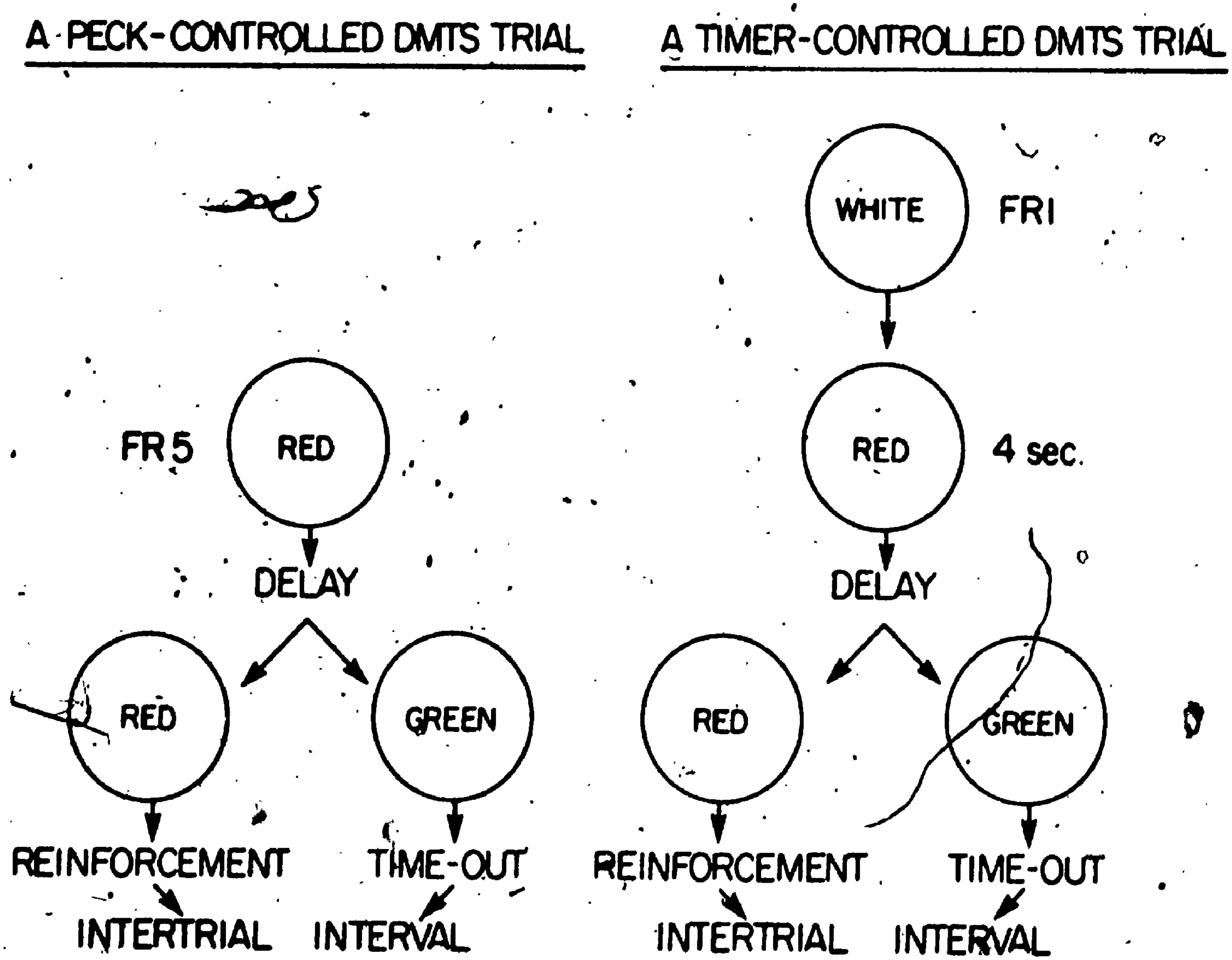
INTRODUCTION

The Delayed Matching-To-Sample Paradigm

The experiments to be reported in this paper involve the use of the delayed matching-to-sample (DMTS) technique to investigate short-term memory (STM) in the pigeon. Several investigations have employed the DMTS task to study STM in the monkey (D'Amato & O'Neill, 1971; D'Amato & Worsham, 1972; Etkin, 1972; Etkin & D'Amato, 1969; Jarrard & Moise, 1970; Jarvik, Goldfarb, & Carley, 1969; Moise, 1970; Worsham & D'Amato, 1973) and in the pigeon (Blough, 1959; Berryman, Cumming, & Nevin, 1963; Cumming & Berryman, 1965; Grant & Roberts, 1973; Roberts, 1972; Roberts & Grant, 1974; Smith, 1967; Zentall, 1973). In DMTS, the sample stimulus is presented, withdrawn, and presented again along with one or more additional stimuli. The animal is allowed to choose one of these stimuli and is reinforced for choosing the stimulus which matches the sample.

Two types of DMTS trials, peck-controlled and timer-controlled, can be distinguished depending upon whether the termination of the sample stimulus is dependent upon the number of times a response is made to the sample (peck-controlled) or upon the passage of time (timer-controlled). An example of a peck-controlled DMTS trial is shown in Fig. 1. The sample stimulus, in this case red, remains illuminated until a certain number of responses has been completed, in this case five. Following the completion of the ratio, the delay is introduced followed by the illumination of the side keys with matching and non-matching colors. An example of a timer-controlled DMTS trial is also shown in Fig. 1. Each trial begins with the presentation of a white

Figure 1. An illustration of the sequence of events in DMTS. (The left side illustrates a peck-controlled DMTS trial and the right side illustrates a timer-controlled DMTS trial).

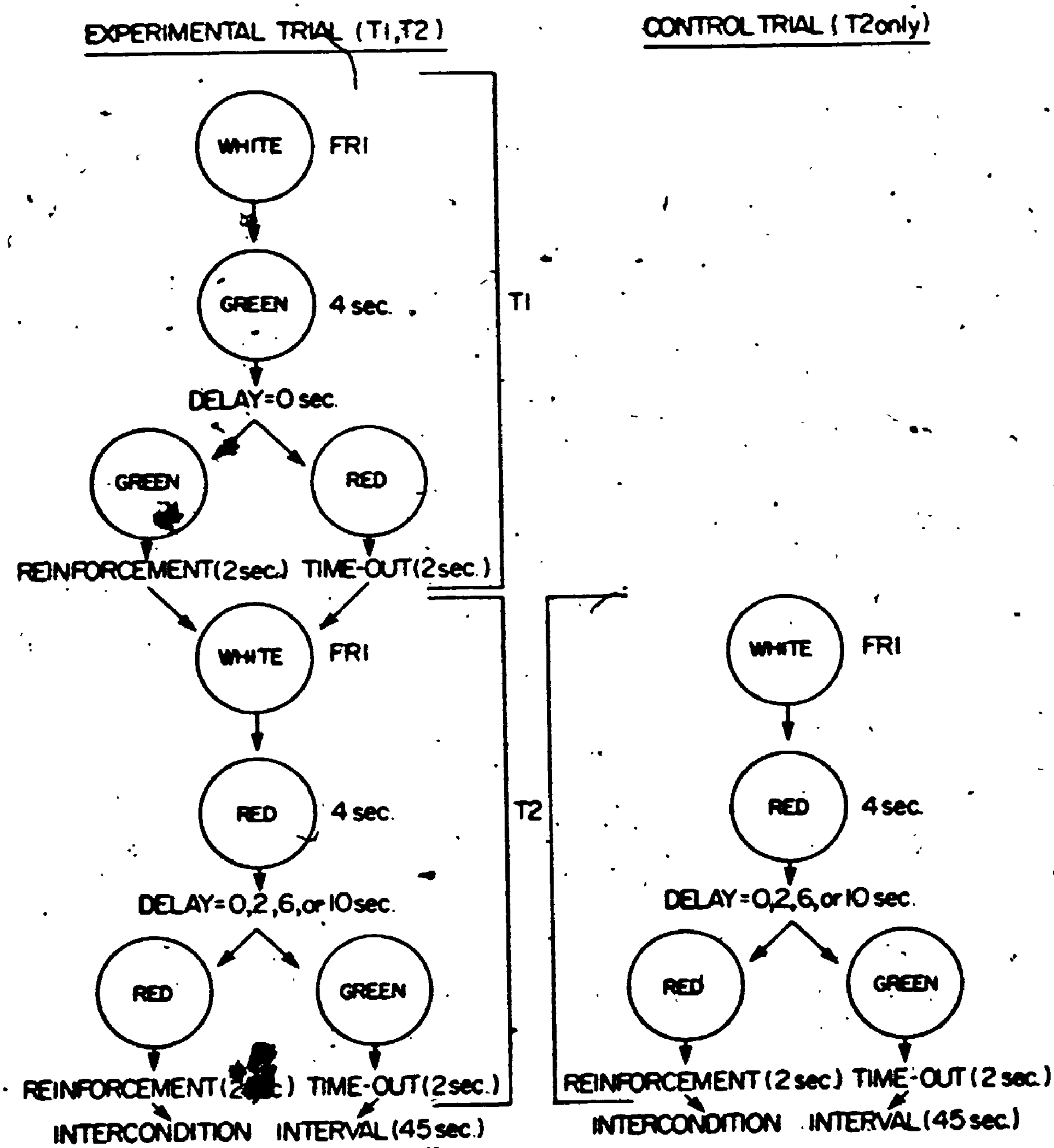

A PECK-CONTROLLED DMTS TRIAL
FR 5
RED
DELAY
RED
GREEN
REINFORCEMENT
TIME-OUT
INTERTRIAL
INTERVAL
A TIMER-CONTROLLED DMTS TRIAL
WHITE
FRI
RED
4 sec.
DELAY
RED
GREEN
REINFORCEMENT
TIME-OUT
INTERTRIAL
INTERVAL

light on the center key. Following the completion of some attending response to the white key, such as pecking the key once, the sample stimulus is presented. The sample remains illuminated until the prescribed exposure time has elapsed, in this case 4 sec. On timer-controlled trials, the sample stimulus exposure duration is completely independent of the number of times the animal responds to the sample stimulus. When the exposure time has elapsed, the center is darkened and the delay interval is introduced. Following the delay, the side keys are illuminated with matching and nonmatching colors. In both peck-controlled and timer-controlled DMTS, the animal is reinforced for responding to the matching side key color.

The Intertrial Interference Paradigm

The experiments to be reported in this paper were designed to investigate the effect of prior learning on the retention of subsequent learning in pigeon STM. The general paradigm employed involved two conditions, an experimental condition and a control condition. Both conditions involved the use of timer-controlled DMTS trials. An example of experimental and control trials is shown in Fig. 2. In the experimental condition, the side key choice on an initial DMTS trial (T1) is followed, two seconds later, by a second DMTS trial (T2). In the control condition, T1 is not presented and T2 occurs in isolation. The comparison of interest is between the percentage of correct choices on T2 in the experimental and control conditions. Since T2 is identical in the experimental and control conditions, any difference between the percentage of correct choices on T2 in the two conditions can be attributed to the effect of prior learning, T1, on the retention of subsequent

Figure 2. The sequence of events in the intertrial interference paradigm. (An experimental trial is illustrated on the left and a control trial is illustrated on the right).



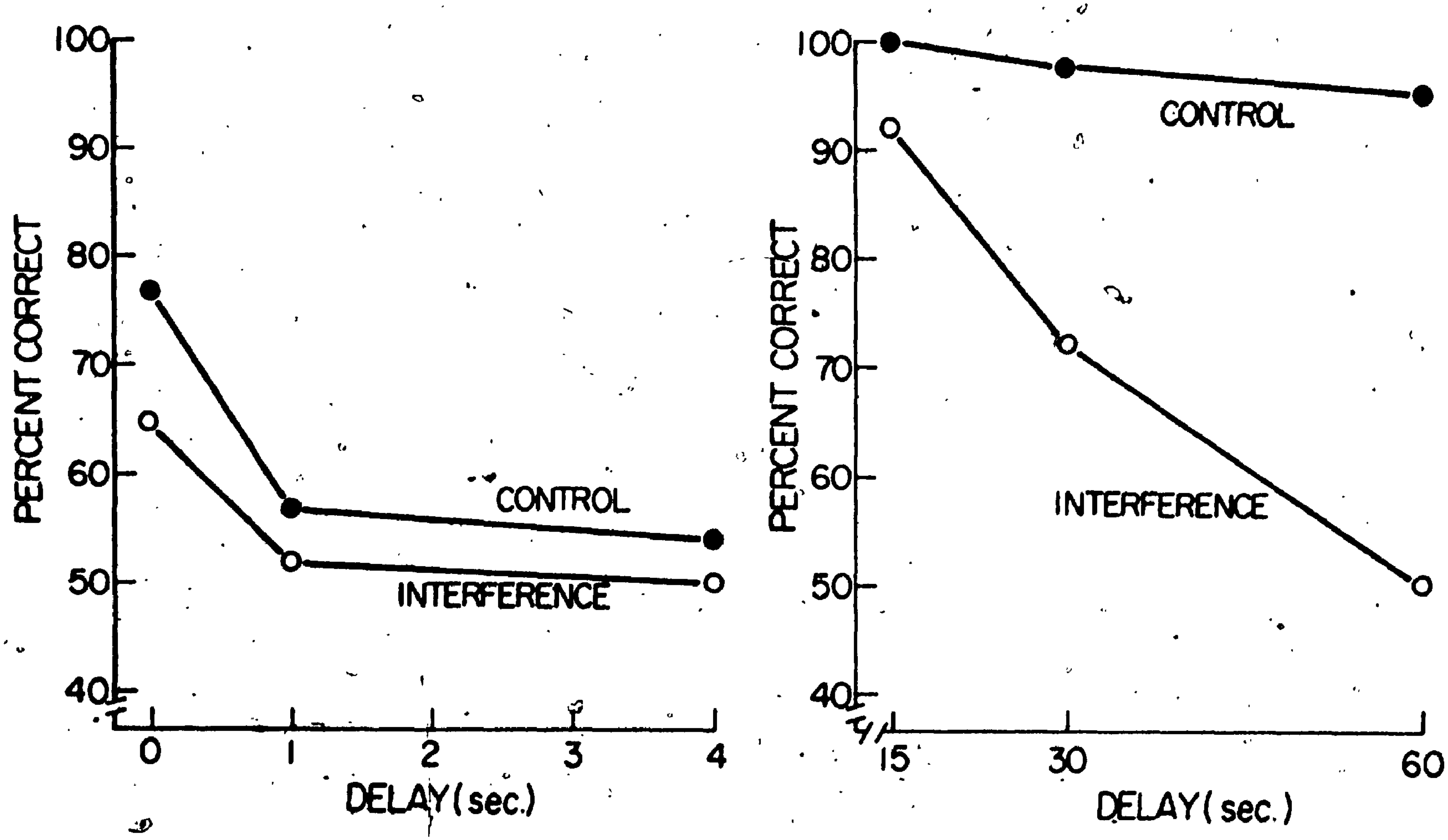
EXPERIMENTAL TRIAL (T1,T2)
CONTROL TRIAL (T2 only)
WHITE
FR1
GREEN
4 sec.
DELAY=0 sec.
GREEN
RED
REINFORCEMENT(2sec.)
TIME-OUT(2sec.)
T1
WHITE
FR1
RED
4 sec.
DELAY=0,2,6,or 10sec.
RED
GREEN
TIME-OUT(2sec.)
INTERCONDITION
INTERVAL(45sec.)
T2
WHITE
FR1
RED
4 sec.
DELAY=0,2,6,or 10 sec.
RED
GREEN
REINFORCEMENT (2 sec.)
TIME-OUT (2 sec.)
INTERCONDITION
INTERVAL (45 sec.)

learning, T2. If the same response was correct on T1 and T2, we might expect T2 performance in the experimental condition to be superior to T2 performance in the control condition (facilitation effect). However, if different responses were correct on T1 and T2, as is the case in Fig. 2, we might expect T2 performance in the experimental condition to be inferior to T2 performance in the control condition (interference effect). The present research was concerned only with the case in which different responses were correct on T1 and T2. Since the interfering item, T1, is a complete trial of learning, the paradigm will be referred to as the intertrial interference paradigm.

Given the intertrial interference paradigm for investigating interference in pigeon STM, we might ask how T1 might be expected to affect T2 performance. Two contrasting types of interference effects have been demonstrated. First, Grant and Roberts (1973), investigating intratrial interference in pigeon STM, found a relatively constant effect of prior learning on the retention of subsequent learning as a function of delay. That is, the magnitude of the interference effect (difference between control and interference conditions) was as great or greater on an immediate retention test as on a delayed retention test. This type of interference effect is shown graphically in the left panel of Fig. 3. In this paradigm, prior learning did not increase the rate at which subsequent learning was forgotten. Grant and Roberts attributed the interference to trace competition between conflicting memories and labelled this type of interference effect the competition effect.

A second type of interference effect is proactive inhibition (PI). PI is defined as a more rapid forgetting of subsequent learning produced

Figure 3. A graphic illustration of the competition effect and the PI effect. (The competition effect in the left panel is based on data from Grant and Roberts, 1973. The PI effect in the right panel is based on data from Harlow, Uehling, and Maslow, 1932).


PERCENT CORRECT
100
90
80
70
60
50
40
CONTROL
INTERFERENCE
0
1
2
3
4
DELAY (sec.)
PERCENT CORRECT
100
90
80
70
60
50
40
CONTROL
INTERFERENCE
15
30
60
DELAY (sec.)

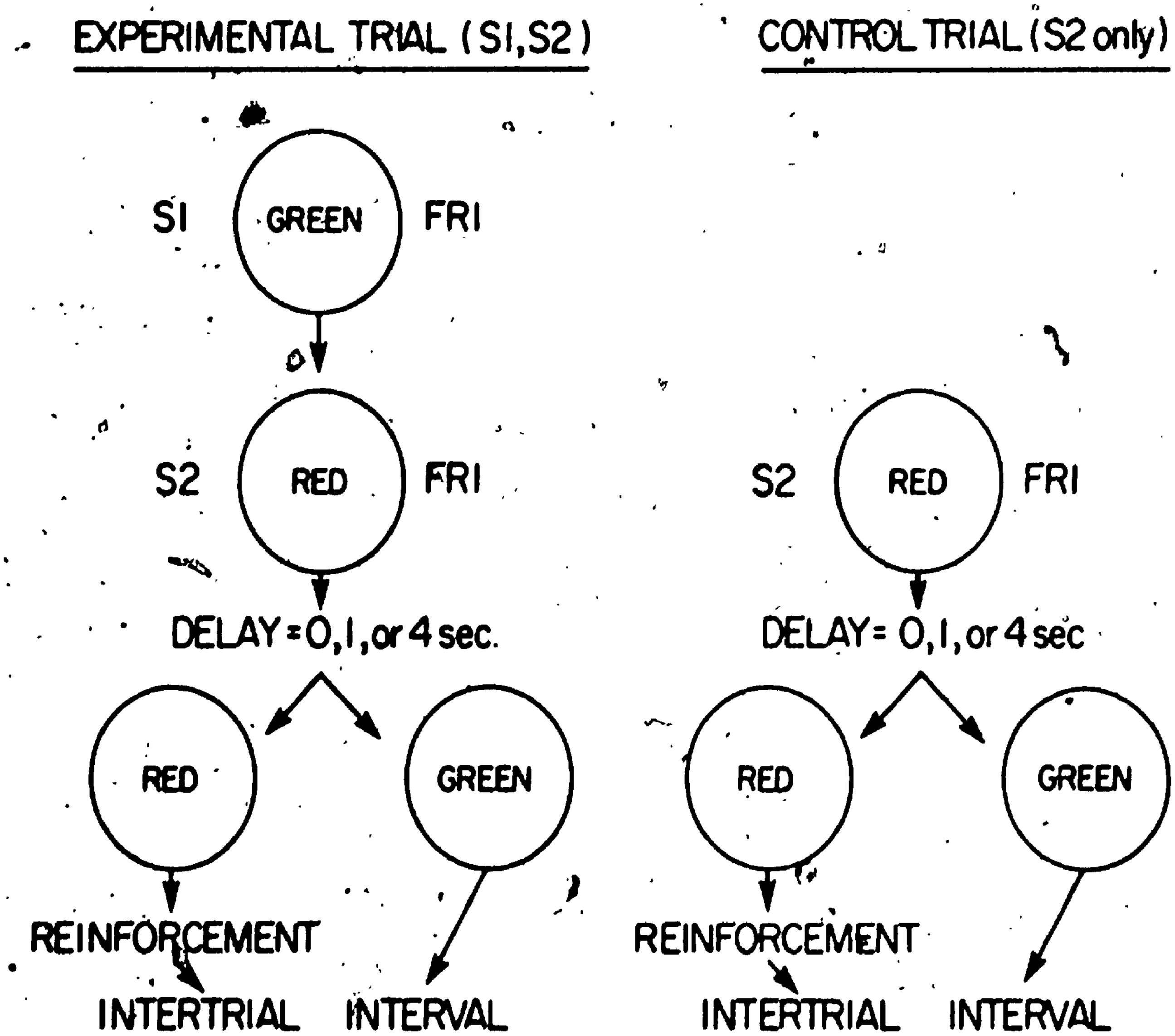
by prior learning. Empirically, PI is demonstrated when the difference between the control and interference conditions increases with increases in the retention interval following subsequent learning. This type of interference effect is shown graphically in the right panel of Fig. 3. Evidence of a PI effect has been obtained in human and primate STM and in rat long-term memory.

Thus, the competition effect and the PI effect represent contrasting types of interference effects. The competition effect is defined as a relatively constant amount of interference as the retention interval is increased. On the other hand, the PI effect is defined as increased interference as the retention interval is increased. These two types of interference effects are discussed in more detail in the following sections.

Intratrial Interference in Pigeon Short-Term Memory

Grant and Roberts (1973) employed a modified peck-controlled DMTS task to investigate intratrial interference in pigeon STM. Two conditions were employed, a control condition and an experimental (interference) condition. An example of control and interference trials is shown in Fig. 4. In the experimental condition, two sample stimuli, S1 and S2, were presented successively at input. Following a delay, S1 and S2 were presented simultaneously for a choice, with choice of S2 designated as correct. In the control condition, only one sample stimulus, S2, was presented at input. Following a delay, S1 and S2 were presented simultaneously for a choice, with choice of S2 designated as correct. Hence, the control condition simply involved the typical peck-controlled DMTS task. The comparison of interest was between the percentage of S2 choices

Figure 4. An illustration of the sequence of events in the intra-trial interference paradigm. (An experimental trial is illustrated on the left and a control trial is illustrated on the right).


EXPERIMENTAL TRIAL (S1,S2)
S1
GREEN
FR1
S2
RED
FR1
DELAY = 0,1, or 4 sec.
RED
GREEN
REINFORCEMENT
INTERTRIAL INTERVAL
CONTROL TRIAL (S2 only)
S2
RED
FR1
DELAY = 0,1, or 4 sec
RED
GREEN
REINFORCEMENT
INTERTRIAL INTERVAL

in the experimental and control conditions. This interference paradigm may be referred to as the intratrial interference paradigm since the interfering item (S1) is presented within the same trial as the test item (S2). Furthermore, the paradigm is intratrial since the animal is not tested for recall of the interfering item.

The results of the Grant and Roberts experimental series on intratrial interference in pigeon STM can be summarized in seven statements. First, on experimental trials, S2 was chosen at the time of test on the majority of trials (greater than 50%). Second, the control condition had a higher percentage of S2 choices than did the experimental condition at each delay (interference effect). Third, the interference effect was constant across delays. Fourth, repetition of S1 at input decreased the percentage of S2 choices at the time of test. Fifth, inserting an inter-stimulus interval of 10 seconds between the termination of S1 and the onset of S2 at input increased the percentage of S2 choices at the time of test. Sixth, repetition of S2 at input increased the percentage of S2 choices at the time of test. Seventh, no interference was obtained if a new stimulus, S3, was substituted for S1 on the retention test.

Grant and Roberts (1973) concluded that any theoretical interpretation of interference effects which predicts an increase in the magnitude of the interference effect as a function of delay was incapable of accounting for their data. This is the case since the magnitude of interference remained constant or decreased as a function of delay. Thus, prior learning, S1, did not affect the rate at which subsequent learning, S2, was forgotten since the maximum amount of interference was obtained at the 0-sec. delay. Grant and Roberts proposed an independence and competition model of interference effects to account for their findings. They proposed that stimulus events are stored as an internal representation of the event, called a memory trace. The strength of the trace increases as a function of stimulus exposure duration and decreases in strength as a function of time following the termination of the event. The competition model holds that traces of events formed in succession have strengths which are independent of one another. While both traces decay with the passage of time, the presence of one trace does not affect the rate at which the other decays. Interference effects are held to be the product of competition between traces, the stronger trace at the time of test tending to determine the choice response. The degree to which the first trace competes for dominance with the second trace is determined by the strength of the first trace in relation to the strength of the second trace; the stronger the first trace in relation to the second trace, the greater the competition and hence the interference.

On the basis of some recent data, Roberts and Grant (1974), the statement that competition is solely determined by the strength of the first trace in relation to the second trace has been revised. In their first two experiments, Roberts and Grant employed the timer-controlled DMTS task to investigate the effect of sample presentation time (PT) upon the percentage of correct choices at the time of test. They found that a sample presented for 4 sec. and allowed to decay for 2 sec. yielded the same percentage of correct choices as a sample presented for 2 sec. and not allowed to decay. Thus, it was proposed that the trace strengths were equal at the time of test. In the third experiment, the data obtained in the first two experiments was used to test the notion that intratrial interference effects are determined by the strength of the two memory traces. A 0-sec. delay was used on all trials. In the first phase of the third experiment, five S1 PT values were used; 2, 3, 4, 5, and 6 sec. The PT of S2 was held constant at 2 sec. A trace strength theory of trace competition would predict that S2 would be chosen at the time of test 50% of the time when S1 was presented for 4 sec. In addition, as the S1 PT decreased from 4 sec. the percentage of S2 choices should rise above 50% and as the S1 PT increased from 4 sec. the percentage of S2 choices should drop below 50%. It was found that when the S1 PT was 4 sec. and the S2 PT was 2 sec., S2 was not chosen 50% of the time, as predicted by the model, but rather 69% of the time. The effect of increasing the S1 PT was to lower the percentage of S2 choices, as predicted by the model. However, even when the S1 PT was 6 sec. the percentage of S2 choices did not drop significantly below chance (50%). In additional phases of their experiment, manipulations were employed to increase the strength of S1 and/or to decrease the strength of S2 at the time of test. None of these manipulations succeeded in producing a percentage of S2 choices that was significantly below chance. Roberts and Grant (1974) concluded that interference effects obtained in the intratrial interference paradigm are jointly determined by the strength of the memory traces and by a recency factor. The effect of this recency factor was to increase the percentage of S2 choices over and above that which would be expected on the basis of the strength of the conflicting memory traces.

In summary, prior learning has been found to interfere with subsequent learning to an equal degree regardless of the length of the retention interval following subsequent learning. Since the maximum amount of interference is obtained on an immediate retention test, prior learning does not affect the rate at which subsequent learning is forgotten. Intratrial interference effects can be accounted for by a model of independent traces and competition between conflicting traces, with the degree of competition being jointly determined by trace strength and by trace recency.

Proactive Inhibition

Another type of interference effect which might be found is proactive inhibition (PI). Proactive inhibition is defined as a more rapid forgetting of subsequent learning when preceded by prior learning than when preceded by a rest interval. According to Spear (1971), PI can be demonstrated only when the original degree of learning of the subsequent task has been equated across experimental and control conditions. Thus, a demonstration of PI requires the use of both an immediate and a later test, and the amount of interference must be greater at the later, compared to the immediate, retention test (p. 50). Evidence of a PI effect has been obtained in both human and primate STM and in rat long-term memory (LTM).

Proactive Inhibition in Human Short-Term Memory

One of the standard techniques for studying human STM was developed by Peterson and Peterson (1959). They briefly presented a trigram composed of three consonants, and then, following a delay of several seconds in which S counted backwards, S was tested for recall of the trigram. This paradigm revealed retention to be a negatively accelerated function of delay. In addition, it was also found that the proportion of correct responses at the short retention intervals (3 and 6 sec.) increased across trials, while the proportion of correct responses at the long retention intervals (15 and 18 sec.) remained relatively constant across trials. Peterson and Peterson attributed the improved performance at the short retention intervals to a practice effect. However, Keppel and Underwood (1962) argued that the improvement in performance at the short retention intervals meant that the degree of learning of the trigram was increasing as trials proceeded. If only practice effects were involved, the improvement in performance with practice should be found at both the short and the long retention intervals. They proposed that no improvement was found at the long retention intervals because the facilitative effect of practice was negated by the detrimental effect of PI. Thus, at the short retention intervals, any interference from prior items was more than compensated for by the practice effect; at long retention intervals, the interference from prior items was of sufficient magnitude to mask the practice effect.

Keppel and Underwood (1962) also presented their own data which supported the contention that PI operates in the Peterson and Peterson STM task. They found that after one prior item the proportion of correct responses at the 3- and 18-sec. retention interval was equal. However, as the number of prior items increased from one to six, the 3- and 18-sec. retention curves diverged. That is, as the number of prior items increased, the proportion of correct responses at the 3-sec.

retention interval remained relatively constant, whereas the proportion of correct responses at the 18-sec. retention interval rapidly decreased. On the basis of these data, they proposed that the negatively accelerated STM retention function was produced by the operation of PI. Keppel and Underwood argued that in the Peterson and Peterson STM paradigm, the learning of a current syllable results in the unlearning or extinction of previously learned associations. Therefore, immediately after learning the current syllable there was relatively little interference due to the extinction of previously learned associations. However, as time passed, previously learned associations spontaneously recovered, resulting in increased interference at the long retention intervals.

Since the original demonstration of PI in human short-term recall memory, the PI effect has become a common finding (see Wickens, 1970). Recently, the PI effect has also been obtained in human STM experiments employing a recognition procedure. Hawkins, Pardo, and Cox (1972) gave Ss a recognition test for List 2 items (4 items per list) after a 0- or 20-sec. retention interval. For half of the Ss, List 2 was preceded by a rest interval (control condition), while for the other half of the Ss, List 2 was preceded by the presentation and recall of List 1 (interference condition). It was found that the two conditions did not differ at the 0-sec. retention interval, but the control condition was superior to the interference condition at the 20-sec. retention interval. Therefore, PI was demonstrated since List 2 was forgotten more rapidly when preceded by prior learning (List 1) than when preceded by a rest interval.

As pointed out by Petrusic and Dillon (1972), Hawkins et al. (1972) did not demonstrate that PI develops using a recognition task since the interfering item (List I) was tested by means of a recall procedure. Petrusic and Dillon (1972) demonstrated that PI does develop when both the interfering item(s) and the test item are tested by means of a recognition procedure. Furthermore, they found the magnitude of the PI effect to be the same in the recognition procedure as in the recall procedure. However, in a later experiment, Dillon and Petrusic (1973), they found slightly greater PI using a recall as opposed to a recognition procedure. Significant PI has also been obtained, using the recognition procedure, by Gorfein and Jacobson (1972).

Proactive Inhibition in Primate Short-Term Memory

In addition to having been found in human recall and recognition STM experiments, PI has also been found in primate STM. Harlow, Uehling, and Maslow (1932), using a spatial delayed-response problem, obtained a PI effect in primate STM. They employed two conditions, a fixed (interference) condition and a random (control) condition. In the fixed condition, the same position was correct four times in succession and then the opposite position was correct on the fifth (test) trial. In the random condition, the correct position was randomly determined, with the restriction that each position was correct equally often, on the four preceding trials. In the random condition the percentages of correct responses on the test trial were 100, 98, and 95 at delays of 15, 30, and 60 sec., respectively. In the fixed condition the percentages of correct responses on the test trial as a function of delay were 92, 72, and 50. The superiority of the random condition over the fixed condition, in percentage terms, was 8, 26, and 45 at the 15-, 30-, 60 sec. delays, respectively. Hence, a PI effect was obtained since the magnitude of the interference effect increased as a function of the delay on the test trial.

Proactive Inhibition in Rat Long-Term Memory

Evidence of a PI effect has also been obtained in rat LTM studies. Investigations of PI in rat LTM have involved first training the animals to make some response, R1, then training them to make some antagonistic response, R2. At some time following the learning of R2, the animals are placed in the situation in which they learned R1 and R2 and allowed to make either of the previously learned responses, with response R2 designated as correct. The typical finding in this situation was that R2 dominated at short delays after learning and became progressively less dominant as the delay increased. The interference condition was equivalent to the control condition (learned only R2) in retention of R2 on an immediate retention test; with the passage of time, the interference condition showed more rapid forgetting of R2 than the control condition. To account for these findings, Spear (1971, 1973) proposed a memory attribute model of PI in rat LTM. Spear proposed that immediately after learning R2, more cues are available for retrieving memories of R2 than of R1. However, as the retention interval increases, the proportion of cues available for retrieving memories of R1 increases, thus accounting for the increased tendency to make R1 as the retention interval is increased.

Purpose of the Present Research

The purpose of the experimental series to be reported in this paper was to investigate the effect of prior learning on the retention of subsequent learning in pigeon short-term recognition memory. As is evident from the preceding discussion, the type of interference effect obtained using the intratrial interference paradigm in pigeon STM is radically different from the type of interference effect obtained in human and primate STM and in rat LTM. Not only does the interference effect differ, but the paradigms also differ. One of the major differences involves the nature of the interfering item. In the intratrial interference paradigm, the interfering item consists of an additional stimulus event occurring on the same trial as the to-be-remembered item, while in human and primate STM and in rat LTM interference paradigms, the interfering item consists of a complete trial(s) of learning. The use of the intertrial interference paradigm with the pigeon is an attempt to eliminate this particular difference. By employing this paradigm it should be possible to move closer to discovering whether interference effects found in pigeon STM differ from interference effects found in primate and human STM and in rat LTM.

EXPERIMENT I

The purpose of the first experiment was to investigate the effect of prior learning upon the retention of subsequent learning in pigeon STM, using the intertrial interference paradigm. Two conditions were employed. In the interference condition, an initial timer-controlled DMTS trial, T1, was followed, two seconds later, by a second timer-controlled DMTS trial, T2. In the control condition, T1 was not presented and T2 occurred in isolation. If T1 interferes with T2, then the percentage of correct responses on T2 should be higher in the control condition than in the interference condition. In addition, if PI operates in this paradigm, then the superiority of the control condition over the interference condition should increase as the delay on T2 increases.

Within the interference condition, the effect of the number of times T1 was presented upon T2 retention was assessed by presenting T1 1, 4, or 6 times. In rat LTM studies, increasing the degree of learning of the interfering task increases the PI effect (Spear, Gordon, and Chiszar, 1972). In human STM experiments, PI effects reach asymptote after 3 to 5 items; the presentation of additional items does not affect the magnitude of the interference effect (Loess, 1964; Wickens, 1970). The three levels of T1 presentation were included to determine whether interference effects in pigeon STM increase with increases in the degree of learning of the interfering task, and to determine whether interference effects also reach asymptote in pigeon STM after some limited number of trials.

An additional variable assessed in Exp. I was the method of determining the spatial position of the correct side key on T1 presentations. Two methods of determining the position of the correct side key on each T1 presentation were used. In the random condition, the position of the correct side key was randomly determined on each T1 presentation. In the fixed condition, the position of the correct side key on each T1 presentation was always the same, this position being the incorrect position on T2. The fixed-random factor in the present experiment was the same as the fixed-random factor manipulated by Harlow, Uehling, and Maslow (1932). Harlow et al. found that this factor produced PI in primate STM. However, in their study the fixed-random factor was manipulated within a spatial delayed-response problem, while in the present experiment this factor was manipulated within a visual DMTS problem. It seems reasonable to hypothesize that prior spatial information would interfere more with the retention of subsequent spatial information than with the retention of subsequent visual information. However, even though it is not essential to use spatial information to solve the DMTS problem, pigeons may nevertheless store and remember spatial information. The fixed-random factor was included to assess whether pigeons store, remember, and use spatial information during DMTS and to assess the effect of prior spatial information on subsequent performance.

Method

Subjects. Ten Silver King pigeons served as Ss. The birds were fed ad lib. until their body weights stabilized. Each bird was then reduced to 80% of its ad lib. weight and was maintained at that weight throughout the experiments.

Apparatus. The experiments were conducted in 2 Lehigh Valley test chambers for pigeons, Model 1519D. Each chamber contained a grain aperture and a panel on which 3 keys were horizontally mounted, spaced 2 inches apart. Multi-stimulus projectors, mounted behind each key, were used to present colors on the key. The programming of stimuli, delays, and intertrial intervals was controlled by relays and timers which were activated by a paper-tape reader. Lehigh Valley printing counters, Model 421-09, recorded and printed the choice made by the birds on each trial.

Procedure. In preliminary training, the birds were shaped to peck a white center key to illuminate 2 white side keys, a peck on either side key producing 3 sec. of access to grain. Each animal then began simultaneous matching-to-sample (SMTS) training. Five sequences of 48 trials each were constructed. On each trial, 1 of 3 pairs of stimuli [blue-red (B-R), blue-yellow (B-Y), or green-red (G-R)] was presented. These 3 pairs of stimuli have been found to be highly discriminable for the pigeon (Roberts, 1972). For each of the stimulus pairs, one member was positive on half the trials and the other member was positive on the other half of the trials. Thus, 6 trial types were used (B+R, B+Y, R+G, R+B, Y+B, and G+R). Each trial type appeared 8 times on each sequence; on 4 of the trials the left side key was correct and on the other 4 trials the right side key was correct. On each trial the center key was illuminated with white light, and a single peck on the white center key changed the center key color from white to either blue, green, red, or yellow. A fixed ratio (FR) of 2 was required on the colored center key (sample) on the first day of

SMTS, and the FR was increased by 2 each day until an FR 20 was required. Following the completion of the FR requirement on the sample stimulus, the 2 side keys were illuminated; one side key was the same color as the sample, while the other side key was the alternate color of that particular color pair (the center key remained illuminated until S pecked one of the side keys). A single peck on the side key which matched the sample resulted in 3 sec. of reinforcement. Following a correct side key choice a 10 sec. intertrial interval (ITI) intervened before the next trial began. A single peck on the side key which did not match the sample caused a 6-sec. blackout to occur; following this period, the sample and the side keys were again illuminated (simultaneously) for a second choice. The bird could not begin a new trial until a correct choice had been made on the previous trial.

After each S reached the criterion of 90% or better over a 5 day period, the correction procedure was discontinued and the reinforcement duration was lowered from 3 to 2 sec. Each S continued on this procedure until the criterion of 90% or better over a 5 day period was again reached. When this criterion was met, the S was transferred to 0-sec. delay DMTS.

The same trial sequences and procedure were used for 0-sec. DMTS as was used with SMTS, with 2 exceptions. First, the sample stimulus was terminated just before the side keys were presented. Second, on half of the trials the sample stimulus was illuminated for 6 sec. regardless of how many times S pecked the sample (timer-controlled trial). The other half of the trials continued to be under the control of an FR 20 (peck-controlled trial). Each S continued on this procedure until the criterion of 85% or better over a 5 day period on timer-controlled trials was reached. When this criterion was met, S was transferred to multiple-delay DMTS.

The trial sequences and procedure for multiple-delay DMTS were the same as the trial sequences and procedure used for 0-sec. DMTS except that a delay of 0, 2, 6, or 10 sec. intervened between the termination of the sample and the illumination of the side keys. Each delay occurred 12 times on each sequence, 6 times on peck-controlled trials and 6 times on timer-controlled trials. Each S was run under this procedure for 20 days. Following the 20 days, all Ss were transferred to all timer-controlled trials. The only change in procedure was that all trials were timer-controlled and the sample exposure duration was lowered from 6 to 4 sec. Each S was run under this procedure for 10 days.

Following DMTS training, testing on Exp. I began. The timer-controlled DMTS task was used with delays of 0, 2, 6, and 10 sec. The 3 highly discriminable combinations of side key colors (B-Y, R-G, and B-R) were used. Two main conditions were employed; an interference condition and a control condition. In the interference condition, 2 timer-controlled DMTS trials, T1 and T2, were presented in immediate succession. On T1, the center key was illuminated with white light. A single peck on the white center key produced the sample stimulus, which was presented for 4 sec. The termination of the sample stimulus was followed immediately (i.e., 0-sec. delay) by the illumination of the 2 side keys with matching and nonmatching colors. A single peck on the matching stimulus resulted in a 2-sec. reinforcement, while a single peck on the nonmatching stimulus resulted in a 2-sec. blackout. Immediately following the 2-sec. reinforcement or the 2-sec. blackout, the center key was again illuminated with white light. A single peck on the white center key produced the sample stimulus of T2; the sample being presented for 4 sec. The sample stimulus on T2 was always the member of the color pair which was incorrect on T1. For example, if the color pair R-G was being tested and the color of the sample on T1 was red, then the sample on T2 would be green. Following the termination of the T2 sample, a delay of 0, 2, 6, or 10 sec. occurred before the side keys were illuminated with matching and nonmatching colors. The nonmatching stimulus on T2 was always the same color as the matching stimulus on T1, and the matching stimulus on T2 was always the same as the nonmatching stimulus on T1. In the control condition, T1 was not presented and T2 occurred in isolation. A 45 sec. intercondition interval (ICI) occurred following all T2 trials in both the interference and control conditions. The types of trials generated by combining the interference versus control factor and the color combinations factor are presented in Table 1.

Within the interference condition, the interfering trial, T1, was presented 1, 4, or 6 times before the T2 sample stimulus was presented. Each T1 presentation immediately followed the 2-sec. reinforcement or the 2-sec. blackout following the side key choice on the previous T1 trial. Within each of these 3 interference conditions (1, 4, and 6 T1 presentations), 2 methods of determining the correct side key position on each T1 presentation were used; the random method and the fixed method. In the random method, the position of the correct side key on

Table 1

The types of trials used in Exp. I

	Interference Condition		Control Condition	
Trial	Stimuli	Delay	Stimuli	Delay
T1	B B+R	0		
T2	R R+B	0,2,6,10	R R+B	0,2,6,10
T1	B B+Y	0		
T2	Y Y+B	0,2,6,10	Y Y+B	0,2,6,10
T1	R R+G	0		
T2	G G+R	0,2,6,10	G G+R	0,2,6,10
T1	R R+B	0		
T2	B B+R	0,2,6,10	B B+R	0,2,6,10
T1	Y Y+B	0		
T2	B B+Y	0,2,6,10	B B+Y	0,2,6,10
T1	G G+R	0		
T2	R R+G	0,2,6,10	R R+G	0,2,6,10

each T1 presentation was randomly determined, within the limits of the following restrictions. In the 1 presentation of T1 condition, the right key was correct on 50% of the trials and the left key was correct on 50% of the trials, and the correct side on T1 was the correct side on T2 on 50% of the trials and the incorrect side on the other 50% of the trials. In the 4 presentations of T1 condition, the right key was correct twice and the left key was correct twice within each sequence of 4 T1 trials. In the 6 presentations of T1 condition, the right key was correct 3 times and the left key was correct 3 times within each sequence of 6 T1 trials. Within the limits of the above restrictions, the position of the correct side key on each T1 presentation was determined by appeal to a table of random numbers. In the fixed method, the same position was correct on each T1 presentation, and this position was the incorrect position on T2. In the 1 presentation of T1 condition, the correct position on T1 was always the incorrect position on T2. Combining the 3 interference conditions with the 2 methods of determining the position of the correct side key on each T1 presentation (random-fixed) yields 6 different interference conditions. In Table 2, an example of a trial from each of the 6 interference conditions and the 1 control condition is presented.

A total of 144 different interference trials were used (6 color combinations x 3 T1 presentation levels x 2 positions of the correct side key on T2 x 4 delays on T2 = 144). On 72 of these interference trials the random method of determining the position of the correct side key on T1 presentations was used, while on the other 72 trials the fixed method was used. A total of 48 control trials were used

Table 2

An example trial from each of the seven conditions in

Exp. I

Interference Condition						Control Condition
1 Presentation		4 Presentations		6 Presentations		
R	F	R	F	R	F	
R	R	R	R	R	R	
R+G	GR+	R+G	GR+	R+G	GR+	
		R	R	R	R	
		R+G	GR+	R+G	GR+	
		R	R	R	R	
		GR+	GR+	GR+	GR+	
		R	R	R	R	
		GR+	GR+	R+G	GR+	
				R	R	
				GR+	GR+	
				R	R	
				GR+	GR+	
G	G	G	G	G	G	G
G+R	G+R	G+R	G+R	G+R	G+R	G+R

R = random determination of position of correct side key on T1 presentations

F = fixed determination of position of correct side key on T1 presentations

(6 color combinations x 2 positions of the correct side key on T2 x 4 delays on T2 = 48). Thus, a total of 192 different trials were used. Twelve sequences of 16 trials each were constructed. Of the 16 trials per sequence, 4 were drawn from each of the 3 presentation levels within the interference condition and 4 were drawn from the control condition. Of these 4 trials, 1 trial was drawn from each of the 4 delays. Each bird received each of the 12 trial sequences and each of the 192 different trials once in a 12-day block. The experiment was run for 2 blocks of 12 days (24 days).

Results and Discussion

SMTS. The mean number of days to reach the criterion of 90% or better over a 5 day period was 12.4 days. At this point the correction procedure was discontinued and the reinforcement duration was lowered from 3 to 2 sec. All 10 birds again reached the criterion, 90% or better over a 5 day period, in 5 days. Hence, the removal of the correction procedure and the reduction in reinforcer magnitude did not appreciably affect matching performance.

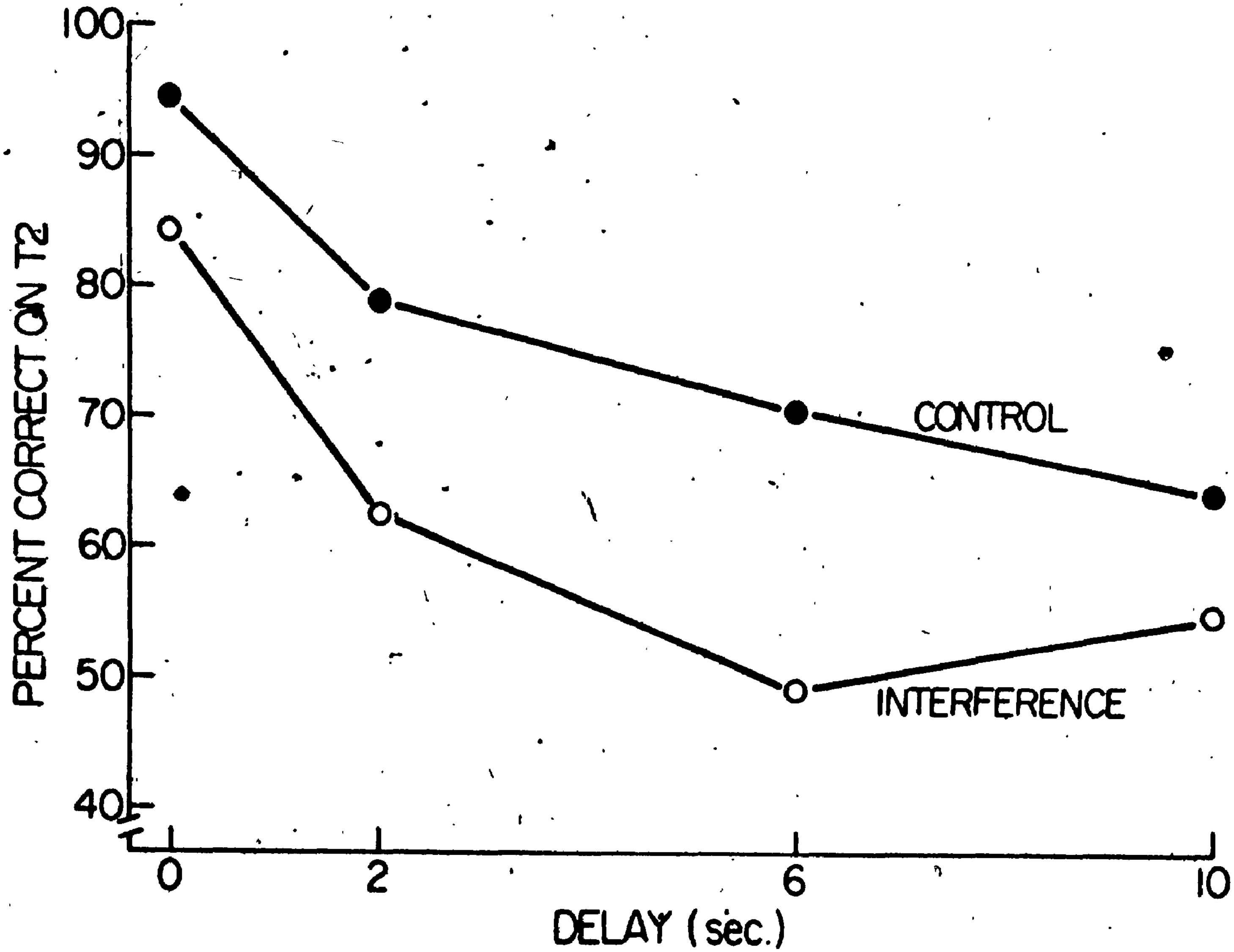
DMTS. The mean number of days to reach the criterion of 85% or better over a 5 day period on 0-sec. DMTS was 6.0 days. The rapid acquisition of 0-sec. DMTS indicates that there was a high degree of positive transfer from SMTS to 0-sec. DMTS. Following 0-sec. DMTS training, the birds were transferred to multiple-delay DMTS. The 4 delays used were 0, 2, 6, and 10 sec. Half of the trials were peck-controlled and the other half of the trials were timer-controlled; the sample presentation time (PT) on timer-controlled trials was 6 sec. On the twentieth and final day of this procedure, the percentages of correct responses at the 0-, 2-, 6-, and 10-sec. delays were 90.0, 81.7, 73.3, and 78.3, respectively. These percentages refer only to timer-controlled trials. Following this 20-day period, the birds were transferred to all timer-controlled trials, and the PT was reduced from 6 to 4 sec. All birds were run under this procedure for 10 days. On the last 5 days, the percentages of correct responses at the 0-, 2-, 6-, and 10-sec. delays were 89.1, 76.8, 69.1, and 66.4, respectively. This last phase concluded preliminary training.

Experiment I. A comparison between the Control Condition and the Interference Condition (collapsed across T1 presentation levels and the fixed-random factor) is presented in Fig. 5. Each point on the control curve is based on 240 observations (24 observations per bird x 10 birds = 240), and each point on the interference curve is based on 720 observations (72 observations per bird x 10 birds = 720). Both delay and conditions strongly influenced retention. The Control Condition had a higher percentage of correct T2 responses than did the Interference Condition at each delay. This finding demonstrates that T1 did interfere with T2. In addition, the curves diverge over the first 6 sec. and then converge at the 10-sec. delay. The difference between the Control and Interference Condition at the 0-, 2-, 6-, and 10-sec. delays, in percentage terms, was 10.1, 17.1, 23.1, and 9.7, respectively. Hence, PI seems to be operating in pigeon STM, at least over the first 6 sec., since prior learning, T1, increased the rate at which subsequent learning, T2, was forgotten.*

A Ss x Delay x Conditions x Blocks of Days Analysis of Variance

*For a discussion of the ceiling effect problem see Appendix XLII.

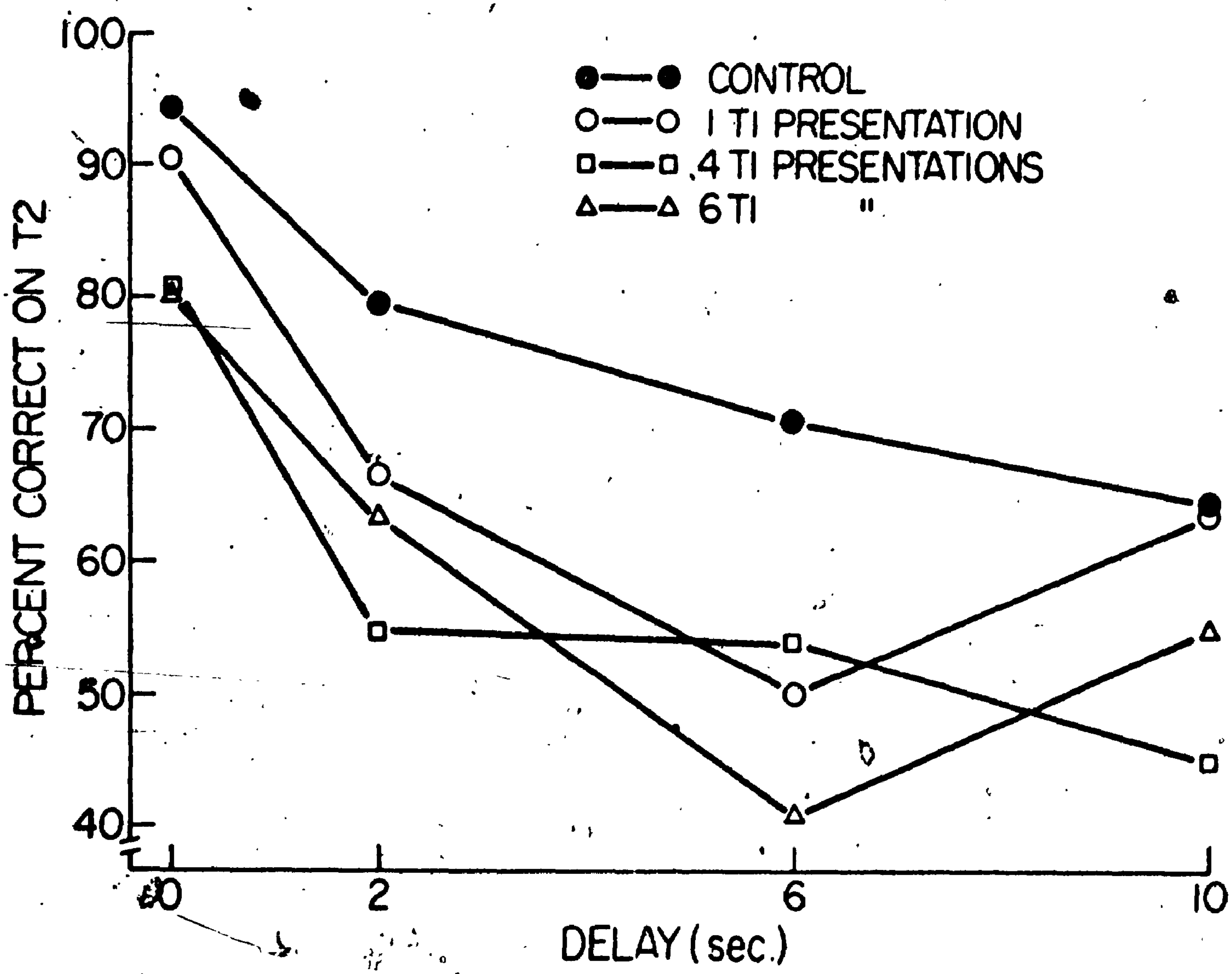
Figure 5. Retention curves for the Interference Condition (collapsed across T1 presentation levels and the fixed-random factor) and the Control Condition in Exp. I.


PERCENT CORRECT ON T2
100
90
80
70
60
50
40
CONTROL
INTERFERENCE
0
2
6
10
DELAY (sec.)

(ANOVA) was performed on the data presented in Fig. 5. This analysis revealed significant effects of delay and of conditions, $p < .001$ in both cases. The effect of blocks of days was not significant, $p > .05$. The only interaction to reach significance was the Conditions x Delay interaction, $p < .01$ (see Appendix I). This interaction indicates that T2 retention was differentially affected by delay in the 2 conditions. In order to determine whether the rate of forgetting over the first 6 sec. was faster in the Interference Condition than in the Control Condition, a Ss x Delay x Conditions x Blocks of Days ANOVA was performed on the data excluding the 10-sec. delay. This analysis revealed significant effects of delay and of conditions, $p < .001$ in both cases. The only other significant term was the Conditions x Delay interaction, $p < .01$ (see Appendix II). Thus, the increase in the magnitude of the interference effect as the retention interval increased from 0 to 6 sec. was statistically reliable, and, therefore, a significant PI effect was demonstrated over the first 6-sec. of delay on T2.

Retention curves for the 1, 4, and 6 presentations of T1 levels and the Control Condition are presented in Fig. 6. Each point in Fig. 6 is based on 240 observations (24 observations per bird x 10 birds = 240). Both delay and conditions strongly influenced retention on T2. An interference effect was obtained in each presentation of T1 level since the Control Condition was superior to each of the Interference Conditions at each delay, with the exception of the equality of the Control and the 1 presentation of T1 Conditions at the 10-sec. delay. The 1 and 6 presentations of T1 levels showed similar effects of T1 upon T2 retention. In each of these 2 conditions, the rate of forgetting

Figure 6. Retention curves for the 1, 4, and 6 presentation of T1 levels (collapsed across the fixed-random factor) and the Control Condition in Exp. I.


CONTROL
1 TI PRESENTATION
4 TI PRESENTATIONS
6 TI "
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

of T2 was greater over the first 6 sec. than in the Control Condition. In both of these Interference Conditions, the retention of T2 was better at the 10-sec. than at the 6-sec. delay. The curve for the 4 presentations of T1 did not parallel the curves for the 2 other Interference Conditions across all 4 delays. The 4 presentations curve paralleled the 1 and 6 presentations curves for the first 2-sec. of T2 delay, then, unlike the 1 and 6 presentations levels, the 4 presentations level showed almost no forgetting of T2 over the next 4 sec. At the 10-sec. delay, the level of T2 retention was lower than at the 6-sec. delay; again, this finding did not follow the pattern of the other 2 presentation levels. Hence, the interpretation of the effect of the number of times T1 was presented upon T2 retention was complicated by the fact that the 4 presentations level differed qualitatively from the other 2 presentation levels. However, comparing the 1 and 6 presentations levels, increasing the number of T1 presentations lowered T2 retention, and thus increased the interference effect, by a relatively constant amount across T2 delays.

A Ss x Delay x Conditions (1, 4, 6 presentations of T1, and control) x Blocks of Days ANOVA was performed on the data presented in Fig. 6. The main effects of delay and of conditions were significant, $p < .001$ in both cases. The main effect of blocks of days was not significant, $F < 1$. The only interaction to reach significance was the Delay x Conditions interaction, $p < .001$ (see Appendix III). The Delay x Conditions interaction was produced by the differential rates of forgetting of T2 across delays as a function of conditions.

In order to further examine the effect of the number of T1 presentations upon T2 retention, ANOVAs were performed comparing each of the T1 presentation levels with the Control Condition. The control versus 1 presentation ANOVA revealed significant effects of delay, $p < .001$, and of conditions, $p < .01$. The Delay x Conditions interaction was also significant, $p < .001$. All other effects were nonsignificant (see Appendix IV). This analysis indicates that the rate of T2 forgetting as a function of delay was affected by 1 presentation of T1. To determine whether the increase in the magnitude of the interference effect over the first 6-sec. of T2 delay was statistically reliable, the above ANOVA was repeated excluding the 10-sec. delay data. The Delay x Conditions interaction was again significant, $p < .001$ (see Appendix V). Thus, a significant PI effect was demonstrated when T1 was presented only once.

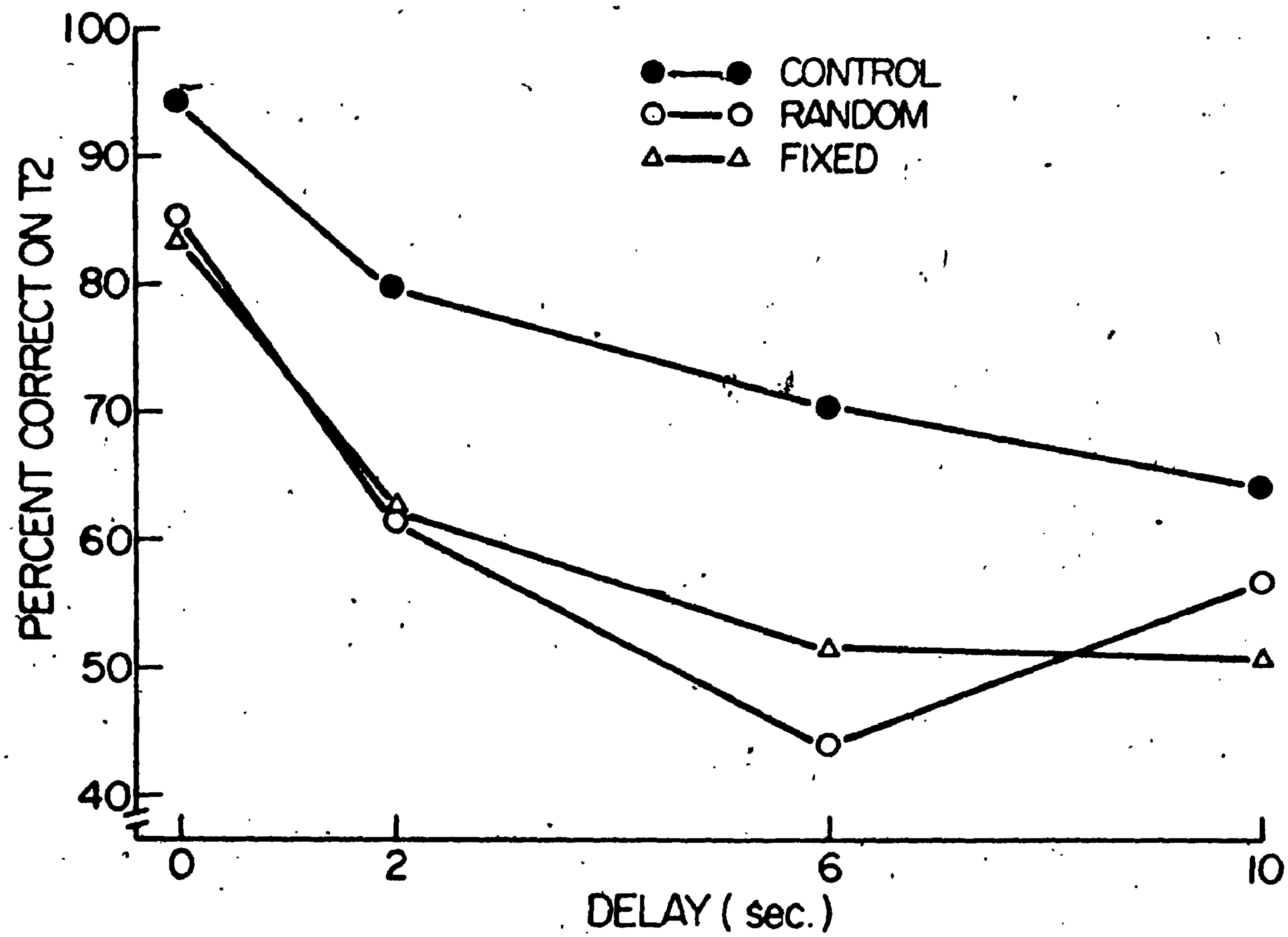
The control versus 4 presentations ANOVA revealed significant effects of delay and of conditions, $p < .001$ in both cases. The only other significant effect was the Delay x Blocks of Days interaction, $p < .05$ (see Appendix VI). This interaction was produced by a much higher percentage of correct T2 choices at the 6-sec. delay in the second block than in the first block. On the basis of this analysis, it may be concluded that presenting the interfering trial 4 times interfered with T2 retention, but that it did not reliably alter the course of T2 forgetting across all 4 delays.

The control versus 6 presentations ANOVA revealed significant effects of delay and of conditions, $p < .001$ in both cases. The only other term to reach significance was the Delay x Conditions interaction, $p < .01$ (see Appendix VII). As in the 1 presentation condition, the ANOVA was again run, this time excluding the 10-sec. delay data. The Delay x Conditions interaction was significant, $p < .01$ (see Appendix VIII). Therefore, a significant PI effect was demonstrated at both the 1 and 6 presentations of T1 levels.

In addition to the above analyses, selected comparisons were made using t-tests. First, as shown in Fig. 6, the retention percentages for the 6 presentations condition at the 6-sec. delay and for the 4 presentations condition at the 10-sec. delay are both below chance (50%), 40.8 and 44.6, respectively. At the 6 presentations 6-sec. delay, 9 of 10 birds scored below 50% and at the 4 presentations 10-sec. delay, 8 of 10 birds scored below 50%. Both percentages were found to be significantly below 50%, $p < .001$ (see Appendix IX). Thus, under certain combinations of T1 presentation levels and of delay, the birds responded significantly more often on the basis of the prior memory, T1, than on the basis of the current memory, T2. Second, the rise in the retention curves from the 6-sec. to the 10-sec. delay in the 1 and 6 presentations conditions was tested by means of t-tests. The rise in the 1-presentation curve was significant at the .001 level and the rise in the 6-presentations curve was significant at the .01 level (see Appendix IX). Both effects were highly consistent with 9 of 10 birds and 8 of 10 birds showing better retention at the 10-sec. than at the 6-sec. delay in the 1- and 6-presentations conditions, respectively. The 3 exceptions all involved cases of no difference; no bird showed better retention at the 6-sec. than at the 10-sec. delay in either the 1- or 6-presentations conditions. Third, although the 4-presentations ANOVA indicated that this condition did not reliably alter the rate of T2 forgetting across all 4 delays, it is possible that more interference was obtained on the 2-, 6-, and 10-sec. retention tests than on the immediate retention test. On the immediate retention test, the Control Condition retention was 13.3 percentage points higher than the 4 presentations Condition retention. On the delayed retention tests, (2, 6, and 10 sec.), the Control Condition retention was, on the average, 20.1 percentage points higher than the 4-presentations Condition retention. This difference in the magnitude of the interference effect on the immediate and delayed retention tests failed to reach significance, $p > .1$ (see Appendix IX). However, the increase in the magnitude of the interference effect from 0 to 2 sec. (13.3 to 23.8) was significant, $p < .05$ (see Appendix IX). Thus, presenting the interfering trial 4 times did result in a significant PI effect over the first 2 sec. of T2 delay.

The data were further analyzed with respect to the fixed-random method of determining the position of the correct side key on each T1 presentation. In Fig. 7 the percentage of correct choices as a function of delay for the Control, Fixed, and Random Conditions are shown. The data for the Fixed and Random Conditions were collapsed across the presentations of T1 factor. Each point on the control curve in Fig. 7 is based on 240 observations (24 observations per bird x 10 birds = 240), and each point on the fixed and random curves is based on 360 observations (36 observations per bird x 10 birds = 360). Interference effects were evident in both the Fixed and Random Conditions. However, the rate of retention loss on T2 was faster in the Random Condition than in the Fixed Condition. In addition, the Fixed Condition demonstrated

Figure 7. Retention curves for the Fixed and Random Conditions (collapsed across T1 presentation levels) and the Control Condition in Exp. I.



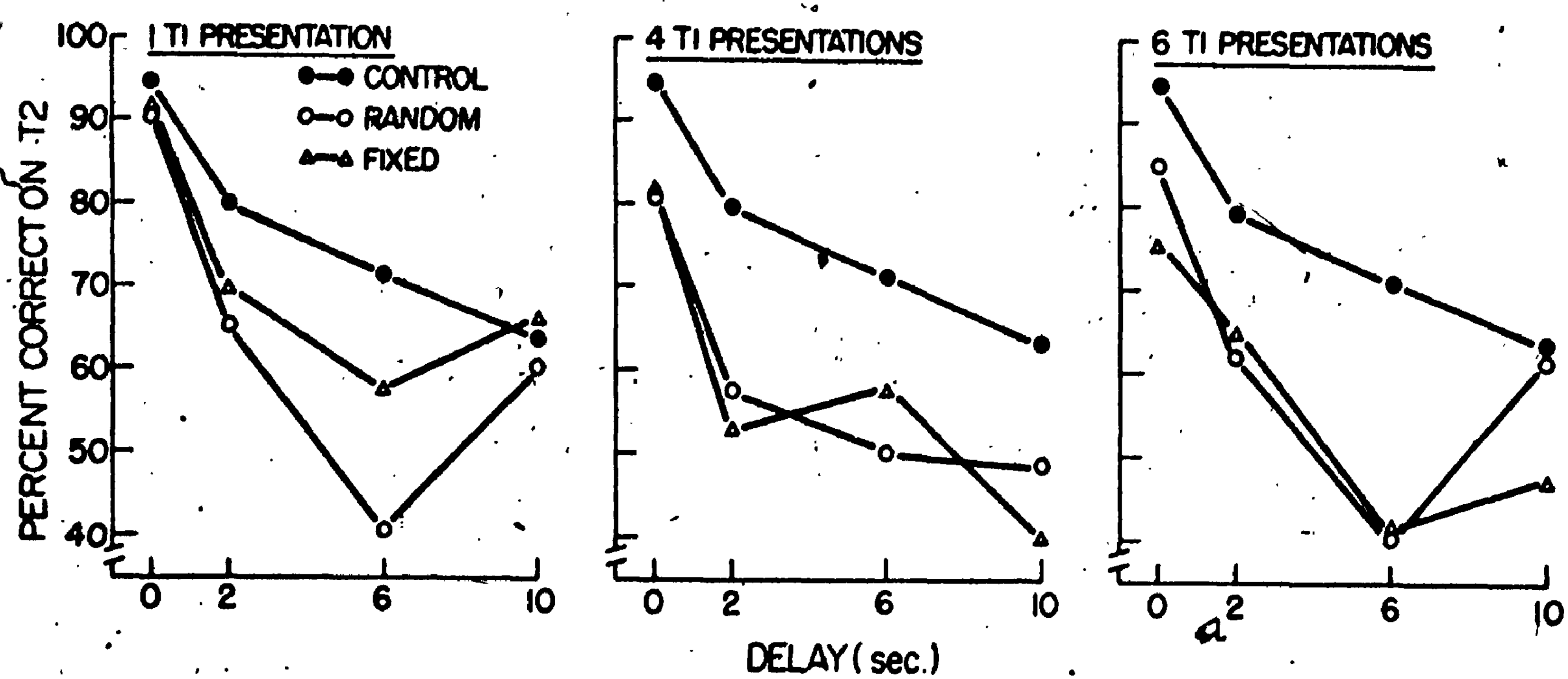
CONTROL
RANDOM
FIXED
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

a slight drop in retention from the 6- to the 10-sec. delay, while the Random Condition showed a sizeable increase in retention over the same period. A Ss x Delay x Conditions (control, fixed, random) x Blocks of Days ANOVA revealed significant effects of delay and of conditions, $p < .001$ in both cases. The effect of blocks of days was not significant, $F < 1$. The Delay x Conditions interaction was the only interaction to reach significance, $p < .01$ (see Appendix X). This analysis indicates that the level of T2 retention was affected by the conditions factor and that the rate of retention loss on T2 was also differentially affected by the conditions factor. A stronger PI effect was evident in the Random Condition than in the Fixed Condition. The magnitude of the interference effect (control percentage minus interference condition percentage) over the 0-, 2-, and 6-sec. delays was 11.2, 16.9, and 18.8 for the Fixed Condition and 9.0, 17.2, and 27.4 for the Random Condition. Thus, while both conditions demonstrated a PI effect over the first 6-sec. of delay on T2, the PI effect was stronger in the Random Condition. The statistical reliability of the difference between the Fixed and Random Conditions was tested by means of t-tests between the 2 conditions at each delay. The difference between the conditions at the 0-, 2-, and 10-sec. delays were not significant, $p > .1$ in all 3 cases. The superiority of the Fixed Condition over the Random Condition at the 6-sec. delay was reliable, $p < .01$ (see Appendix XI). It may be concluded from these statistical tests that the fixed-random factor only affected T2 retention at the 6-sec. retention interval, with the Fixed Condition having a higher percentage of correct responses than the Random Condition. The overall effect was produced by the 1 and 4 presentations of T1 levels; in the 6 presentations Condition, where the fixed-random factor should have the strongest effect, the Fixed and Random Conditions did not differ at the 6-sec. delay.

Retention curves for the Fixed and Random Conditions are plotted separately for each level of T1 presentations in Fig. 8. Each point on the fixed and random curves is based on 120 observations (12 observations per bird x 10 birds = 120), and each point on the control curves is based on 240 observations (24 observations per bird x 10 birds = 240). In the 1 presentation of T1 condition, the Fixed Condition produced less interference than the Random Condition. Furthermore, the superiority of the Fixed over the Random Condition increased over the first 6-sec. of T2 delay, and then decreased slightly at the 10-sec. delay. In the 4 presentations of T1 condition, the effect of the fixed-random factor was less clear. The Random Condition was slightly superior at the 2- and 10-sec. delays, while the Fixed Condition was slightly superior at the 6-sec. delay. In the 6 presentations of T1 condition, where the fixed-random factor would be expected to have the strongest effect, the Random Condition was superior to the Fixed Condition at the 0- and 10-sec. delays, with the 2 conditions showing little difference at the 2- and 6-sec. delays.

A Ss x Delay x Conditions (fixed, random) x Blocks of Days ANOVA was performed on the data within each T1 presentation level. The 1-presentation ANOVA revealed significant effects of delay, $p < .001$, and of conditions, $p < .01$. The effect of blocks of days was not significant, $p > .05$. None of the interaction terms reached significance

Figure 8. Retention curves for the Fixed and Random Conditions at each level of T1 presentations and the Control Condition in Exp. I.



1 TI PRESENTATION
CONTROL
RANDOM
FIXED
4 TI PRESENTATIONS
6 TI PRESENTATIONS
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

(see Appendix XII). The 4 presentations ANOVA revealed a significant effect of delay, $p < .001$; the effect of conditions and of blocks of days were not significant, $p > .05$ in both cases. Two of the interaction terms reached significance; Delay x Blocks of Days and Conditions x Blocks of Days, $p < .05$ in both cases (see Appendix XIII). The Delay x Blocks of Days interaction was produced by a higher level of retention at the 2-sec. delay in the first block than in the second block. The Conditions x Blocks of Days interaction was produced by the fact that in the first block, the Fixed and Random Conditions differed greatly at the 6-sec. delay, but not at the 10-sec. delay. In the second block, this finding was the reverse, the 2 conditions did not differ at the 6-sec. delay, but differed greatly at the 10-sec. delay. The 6 presentations ANOVA revealed significant effects of delay, $p < .001$, and of blocks of days, $p < .05$. The effect of conditions was not significant, $p > .05$. None of the interaction terms reached significance (see Appendix XIV). The significant blocks of days effect was produced by a higher level of T2 retention at the 2- and 10-sec. delays in the second block than in the first block.

The effect of the fixed-random factor within each of the T1 presentations levels was further examined by performing t-tests between the Fixed and Random Conditions at each delay. Of the 12 comparisons made, 10 were not significant, $p > .1$ in all cases. The 2 significant differences between the 2 conditions occurred at the 6-sec. delay in the 1 presentation of T1 condition and at the 10-sec. delay in the 6 presentations of T1 condition, $p < .02$ in both cases (see Appendix XV).

The results of the ANOVAs and the ts revealed that the fixed-random factor had a relatively weak effect upon T2 retention. In addition, the effect of this factor upon T2 retention varied as a function of the level of T1 presentations. The strongest effect of the factor was obtained in the 1 presentation condition, where fixed determination of the correct side key position led to better T2 retention than random determination. In addition, the superiority of the Fixed over the Random Condition increased over the first 6 sec. of T2 delay, and then remained relatively constant or slightly declining. This finding could be accounted for by proposing that following the choice of side A on T1, the bird has a tendency not to select side A again on T2; and that this tendency increases, up to a point, as a function of T2 delay. In the 4 presentations condition, no reliable effect of the fixed-random factor was obtained. In the 6 presentations condition, the Fixed Condition may result in greater interference on an immediate retention test and reliably produces greater interference on a 10-sec. delayed retention test.

Several conclusions can be drawn from the results of the first experiment. First, a reliable PI effect, over the first 6-sec. of T2 delay, was produced using the intertrial interference paradigm. Second, a reliable PI effect was obtained over the first 6-sec. of T2 delay when the interfering trial was presented either 1 or 6 times, but when it was presented 4 times, PI was found only over the first 2-sec. of T2 delay. The reason for the difference in the PI effect in the 4-presentations Condition as opposed to the 1- and 6-presentations Conditions is unclear. Third, the effect of increasing the number of times the interfering trial was presented, from 1 to 6, was to decrease performance by a relatively constant amount across T2 delays. Thus, the magnitude of the PI effect was not affected by the number of T1 presentations. Fourth, the effect of the method of determining the correct side key position on T1 presentations was relatively weak. In the 1 presentation Condition, fixed determination was superior to random determination; and the superiority increased over the first 6-sec. of T2 delay. In the 4 presentations Condition, the fixed-random factor produced no reliable differences. In the 6 presentations Condition, the Fixed Condition produced more interference than the Random Condition at the 0- and 10-sec. delays on T2.

EXPERIMENT II

The main purpose of the second experiment was to assess the effect of having the correct stimulus on T1 appear or not appear on the T2 recognition test. Hawkins, Pardo, and Cox (1972), investigating PI in human STM, did obtain a PI effect when the incorrect alternatives on the recognition test were items which had been previously presented, but did not obtain a PI effect when the incorrect alternatives were items that had not been previously presented. However, two other studies, Petrusic and Dillon (1972) and Dillon and Petrusic (1973), have found no effect of the type of incorrect alternative employed on the PI effect in human short-term recognition memory. That is, a PI effect was obtained both when previously presented items were used as incorrect alternatives and when new items were used as incorrect alternatives. This same result has also been obtained by Gorfein and Jacobson (1972) who concluded that "... whatever prior items do to produce PI, having them present as recognition alternatives has no specific influence on the likelihood of an error" (p. 214).

Grant and Roberts (1973), investigating intratrial interference in pigeon STM, failed to obtain an interference effect when a stimulus, which had not previously been presented on that trial, appeared on the recognition test along with the correct stimulus. They concluded that interference effects are the product of competition between conflicting memories rather than the product of encoding or storage failure.

The present experiment employed two main interference conditions. In the sample present (SP) condition, the sample stimulus on T1 was the incorrect stimulus on T2. In addition, the incorrect color on T1 was the correct color on T2. Thus, in condition SP, correct and incorrect colors on T1 were reversed on T2. In the other interference condition, the sample absent (SA) condition, the sample stimulus on T1 did not appear on the T2 recognition test. Within the SA condition, three subconditions can be differentiated on the basis of what role the incorrect color on T1 played on T2. In subcondition A, the incorrect color on T1 was the incorrect color on T2. In subcondition B, the incorrect color on T1 was the correct color on T2. In subcondition C, the incorrect color on T1 did not appear on the T2 recognition test. Thus, if having the T1 sample stimulus present, and incorrect, on the T2 recognition test is the critical factor responsible for producing PI in pigeon STM, then one would expect PI in the SP condition, but not in the SA condition. If, however, PI is demonstrated in both the SP and SA conditions, then some factor other than the presence of the T1 sample must be responsible for producing PI in pigeon STM.

If we assume that some inhibition against choosing the incorrect stimulus on T1 builds up on T1, then the SA subconditions would be expected to differ with respect to the percentage of correct choices on T2. Specifically, we would expect A to have a higher percentage of correct choices than C, and C to have a higher percentage of correct choices than B (i.e., A > C > B).

<u>Method</u>

<u>Subjects</u>. Same as in Exp. I.

<u>Apparatus</u>. Same as in Exp. I.

Procedure. Three conditions were employed; 2 interference conditions and a control condition. In both interference conditions, the interfering trial (T1) was presented once. Immediately following the 2-sec. reinforcement or the 2-sec. ITI following the side key choice on T1, T2 was presented. In one interference condition, the T1 sample stimulus was the incorrect stimulus on T2. This condition will be referred to as the sample present or SP condition. In the other interference condition, the T1 sample stimulus did not appear on the T2 recognition test. This condition will be referred to as the sample absent or SA condition. In the control condition, T1 was not presented and T2 occurred in isolation. The types of trials used in Exp. II are presented in Table 3. As can be seen in Table 3, 3 subconditions can be differentiated within the SA condition on the basis of what role the incorrect color on T1 assumes on T2. In A, the incorrect color on T1 was the incorrect color on T2. In B, the incorrect color on T1 was the correct color on T2. In C, the incorrect color on T1 did not appear on the T2 recognition test.

A total of 144 different trials were used (3 conditions x 6 color combinations x 2 positions of the correct side key on T2 x 4 delays on T2 = 144). (Note: the position of the correct side key on T1 was randomly determined. Therefore, on half of the interference trials the same position was correct on T1 and on T2, while on the other half of the interference trials opposite positions were correct on T1 and on T2). Four trial sequences of 36 trials each were constructed. Twelve trials were drawn from each of the 3 conditions; 3 of the 12 trials were drawn from each of the 4 delays. Each bird received each

Table 3

The types of trials used in Exp. II.

Trial	Sample Present (SP)		Sample Absent (SA)		Control	
	Stimuli	Delay	Stimuli	Delay	Stimuli	Delay
T1	B	0	Y	0		
T2	B+R R R+B	0,2,6,10	Y+B R R+B A	0,2,6,10	R R+B	0,2,6,10
T1	B	0	R	0		
T2	B+Y Y Y+B	0,2,6,10	R+G Y Y+B C	0,2,6,10	Y Y+B	0,2,6,10
T1	R	0	B	0		
T2	R+G G G+R	0,2,6,10	B+Y G G+R C	0,2,6,10	G G+R	0,2,6,10
T1	R	0	G	0		
T2	R+B B B+R	0,2,6,10	G+R B B+R A	0,2,6,10	B B+R	0,2,6,10
T1	Y	0	R	0		
T2	Y+B B B+Y	0,2,6,10	R+B B B+Y B	0,2,6,10	B B+Y	0,2,6,10
T1	G	0	B	0		
T2	G+R R R+G	0,2,6,10	B+R R R+G B	0,2,6,10	R R+G	0,2,6,10

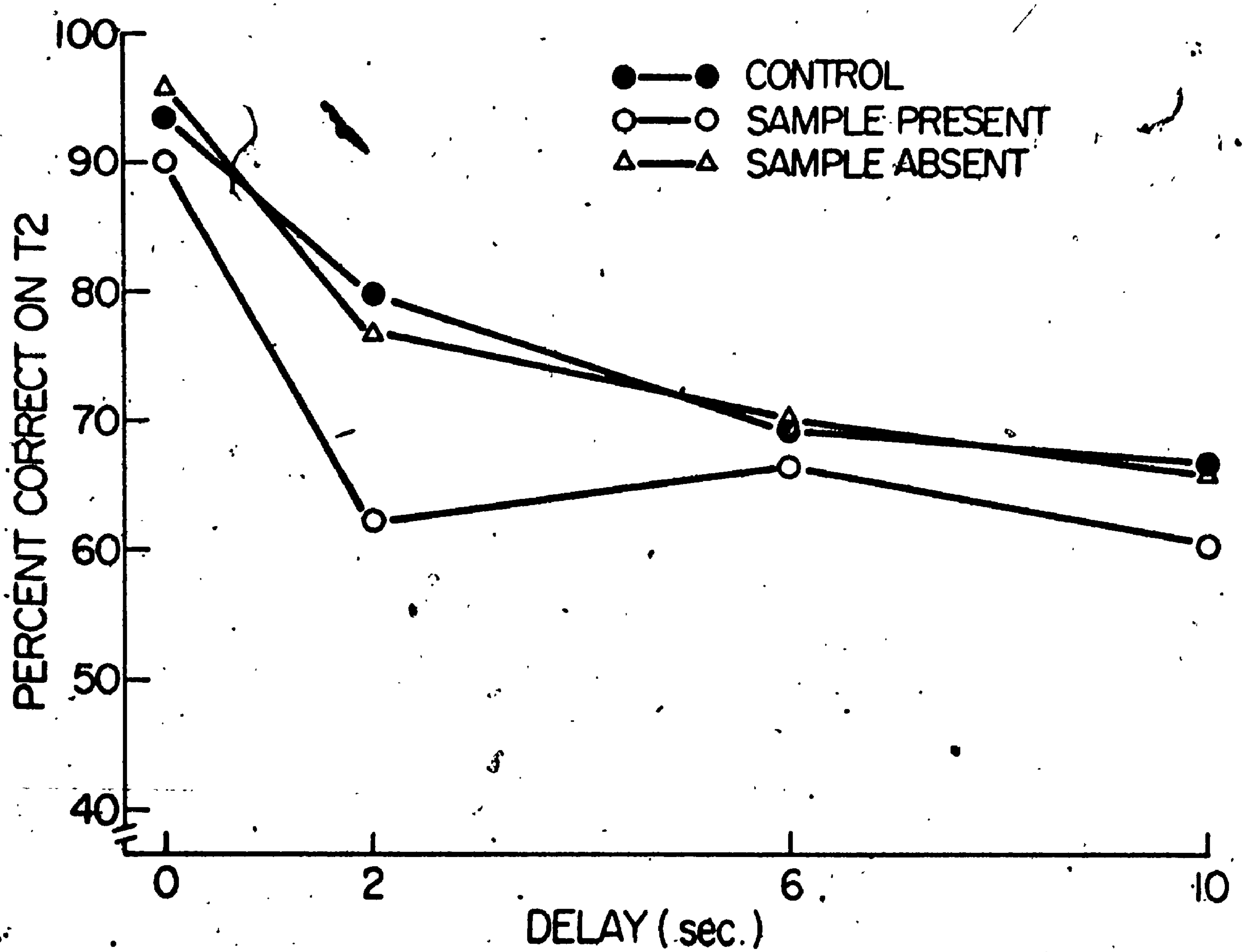
of the 4 trial sequences and each of the 144 different trials once in a 4-day block. All other aspects of the procedure were the same as in Exp. I.

Results and Discussion

Retention curves for the Sample Present (SP), Sample Absent (SA), and Control Conditions are shown in Fig. 9. Each point in Fig. 9 is based on 360 observations (36 observations per bird x 10 birds = 360). The difference between the Control and SA Condition (control percentage minus SA percentage) at the 0-, 2-, 6-, and 10-sec. delays was -2.8, 2.8, -1.4, and 1.4 respectively. Thus, no interference effect was evident in the SA Condition. The difference between the Control and SP Condition across delays was 3.3, 16.9, 1.9, and 5.6, respectively. Thus, an interference effect was obtained in the SP Condition since the Control Condition was superior to the SP Condition at each delay. Further, a PI effect was evident, over the first 2-sec. of delay, in the SP Condition. The reason for not obtaining a PI effect over the first 6-sec. of T2 delay, as was obtained in Exp. I, is unclear.

A Ss x Delay x Conditions x Blocks of Days ANOVA was performed on the data in Fig. 9. The ANOVA revealed significant effects of delay, $p < .001$, and of conditions, $p < .01$. The only other significant term was the Delay x Conditions interaction, $p < .05$ (see Appendix XVI). This analysis indicates that the T2 retention function was differentially affected by the conditions factor. To further examine the effect of the SA and SP Conditions on T2 retention, separate ANOVAs were performed comparing each interference condition

Figure 9. Retention curves for the Sample Present (SP), Sample Absent (SA), and Control Conditions in Exp. II.

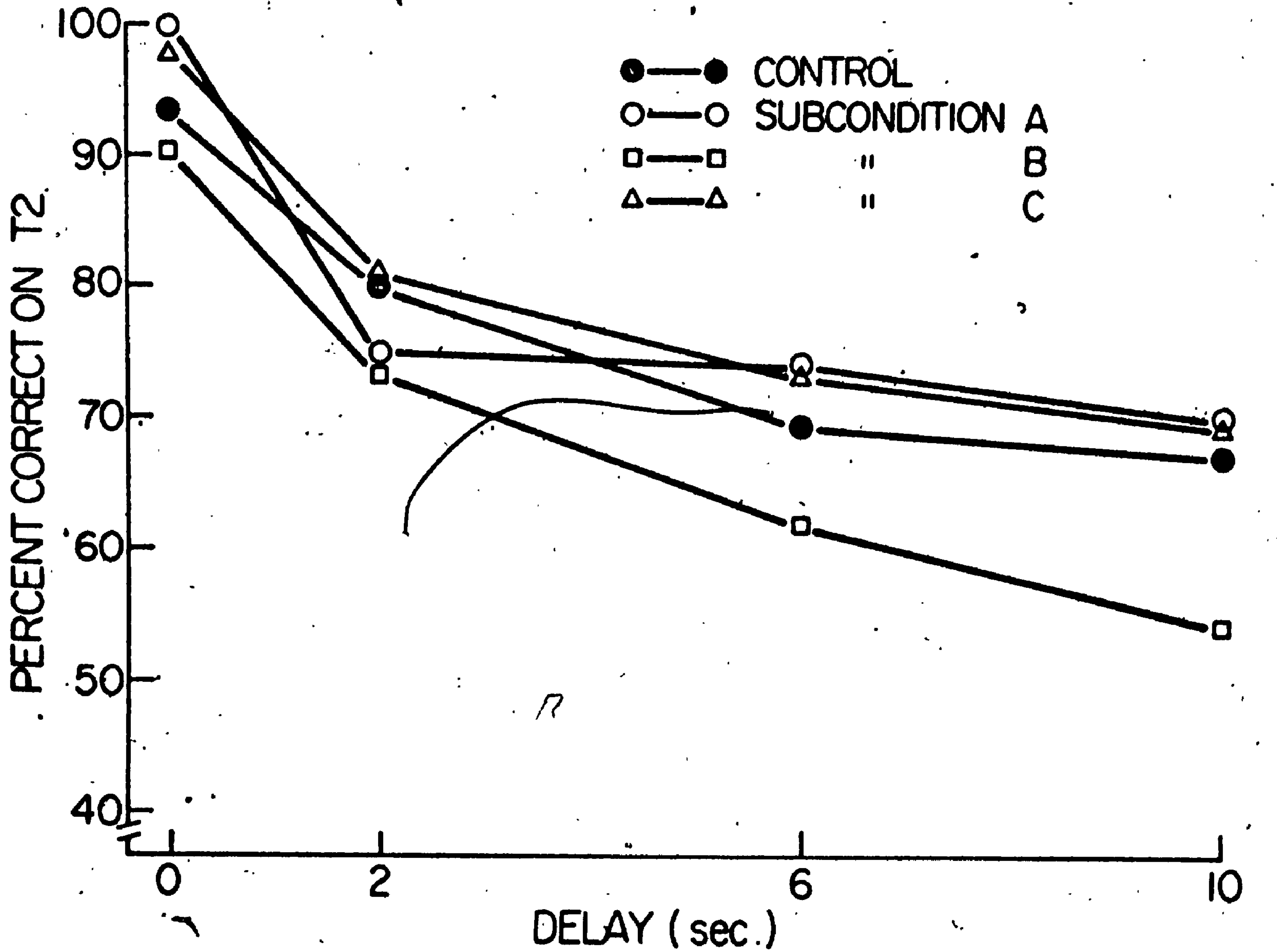

CONTROL
SAMPLE PRESENT
SAMPLE ABSENT
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

with the control. In the Control-SA ANOVA, the only significant effect was that of delay, $p < .001$ (see Appendix XVII). In the Control-SP ANOVA, the main effects of delay, $p < .001$, and of conditions, $p < .05$, were significant. The only other significant term was the Delay x Conditions interaction, $p < .05$ (see Appendix XVIII). On the basis of these analyses, it may be concluded that one factor critical for producing PI in pigeon STM is having the correct alternative on T1 (i.e., the T1 sample) present and incorrect on T2. This finding supports the notion that PI in pigeon STM is produced by the competition of conflicting memories at the time of test.

Retention curves for the A, B, and C subconditions of the SA Condition and the Control Condition are presented in Fig. 10. Each point on the A, B, and C subcondition curves is based on 120 observations (12 observations per bird x 10 birds = 120), and each point on the control curve is based on 360 observations (36 observations per bird x 10 birds = 360). The A and C subconditions were superior to the Control Condition at each delay, with exception of the A subcondition at the 2-sec. delay. On the other hand, an interference effect was evident in subcondition B, since B was inferior to the control at each delay. The magnitude of interference across the 0-, 2-, 6-, and 10-sec. delays, in percentage terms, was 1.9, 6.1, 6.7, and 11.9, respectively. Hence, a PI effect was evident in subcondition B since more interference was obtained at the latter retention intervals than was obtained on the immediate test.

A Ss x Delay x Conditions x Blocks of Days ANOVA was performed on the data shown in Fig. 10. The ANOVA revealed significant effects

Figure 10. Retention curves for the A, B, and C subconditions of the SA Condition and the Control Condition in Exp. II.


CONTROL
SUBCONDITION A
" B
" C
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

of delay, $p < .001$, and of conditions, $p < .05$. The effect of blocks of days and all interactions were nonsignificant (see Appendix XIX). To further examine the effect of the 3 subconditions on the percentage of correct T2 responses, separate ANOVAs were performed comparing each subcondition with the Control Condition. In all 3 ANOVAs, the only significant effect was that of delay, $p < .001$ in all 3 cases (see Appendices XX, XXI, and XXII). On the basis of these statistical analyses, it can be concluded that the percentage of correct responses on T2 was affected by the conditions factor (A, B, and C subconditions, and Control Condition), but that the rate of forgetting of T2 was not affected by the conditions factor. In addition, none of the 3 subconditions reliably differed from the control.

The subcondition B-Control Condition ANOVA, mentioned above, indicated that the increase in the rate of forgetting of T2 in subcondition B over the 3 portions of the retention interval (0 to 2, 2 to 6, and 6 to 10) was not statistically reliable. However, the possibility remained that a significantly greater retention loss from the 0- to the 10-sec. delay occurred in subcondition B. In subcondition B, the percentage of correct T2 responses fell from 91.7 at the 0-sec. delay to 54.2 at the 10-sec. delay; a retention loss of 37.5 percentage points. In the Control Condition, the percentage of correct T2 responses fell from 93.1 at the 0-sec. delay to 66.1 at the 10-sec. delay; a retention loss of 27.0 percentage points. Thus, retention dropped 10.5 percentage points more in subcondition B than in the Control Condition. By two-tailed *t*-test, it was found that a significantly greater retention loss occurred in subcondition B than in the Control Condition from the 0- to the 10-sec. retention test ($t = 2.34$, $df = 9$, $p < .05$). Thus, subcondition B resulted in significant PI.

Several conclusions can be drawn from the results of the present experiment. First, when the test trial, T2, does not contain either the correct or incorrect stimulus from T1, T1 does not interfere with T2. If only the incorrect color on T1 appears on T2, and remains incorrect on T2, T1 does not interfere with T2. In fact, in these 2 cases, T1 may slightly facilitate T2 performance; perhaps this may be due to a slight "warm-up" effect provided by T1. Second, when the correct stimulus on T1 is incorrect on T2 and the incorrect stimulus on T1 is correct on T2, PI results. Third, when the incorrect stimulus on T1 becomes correct on T2, PI also results. Fourth, the results of the present experiment rule out the notion that PI effects in pigeon STM may be the product of encoding and/or storage failure. On the other hand, the results provide strong support for the competition of conflicting memories at retrieval interpretation of PI in pigeon STM.

EXPERIMENT III

The type of interference effect obtained in the intertrial interference paradigm (i.e., PI effect) differs radically from the type of interference effect obtained in the intratrial interference paradigm (i.e., competition effect). The purpose of the third experiment was to attempt to discover the critical difference between these paradigms which is responsible for producing the different types of interference effects. Five conditions were employed, 4 interference conditions and 1 control condition. The 4 interference conditions differed with respect to the type of event used as T1. In Condition I, a complete trial was used as T1. In Condition II, the sample stimulus and the correct side key were presented; no incorrect stimulus was presented on T1. In Condition III, no sample stimulus was presented and the correct stimulus appeared as a side key; again, no incorrect stimulus was presented. In Condition IV, only the sample stimulus was presented and no side key response was made. In Condition V, the control condition, no T1 event occurred and T2 was presented in isolation. Hence, Condition I represents the intertrial interference paradigm and Condition IV represents the intratrial interference paradigm, with Conditions II and III representing intermediate stages between the 2 paradigms.

On the basis of the findings of Exps. I and II, it was predicted that Condition I, the intertrial interference condition, would produce a PI effect. On the basis of the findings of Grant and Roberts (1973), and to a lesser extent on the findings of Roberts and Grant

(1974), Condition IV, the intratrial interference condition, should not produce a PI effect, but rather a competition effect. The critical question was, what type of interference effect, if any, would be produced in Conditions II and III. If simply pecking the side key and being reinforced is the critical factor responsible for producing PI, then Condition III should demonstrate PI. However, if it is necessary to be stimulated by the sample and to peck the side key and be reinforced, then Condition II should produce PI. On the other hand, it may be necessary to be stimulated by the sample and to make a side key choice between matching and nonmatching colors; in this case, only Condition I would be expected to produce PI.

Method

<u>Subjects</u>. Same as in Exps. I and II.

<u>Apparatus</u>. Same as in Exps. I and II.

<u>Procedure</u>. An example of a trial for each of the 6 color combinations within each of the 5 conditions is shown in Table 4. The 5 conditions differed with respect to the type of event which constituted T1. In Condition I, a sample stimulus was presented and followed immediately by the illumination of the side keys with matching and nonmatching colors. A single peck on the matching stimulus resulted in a 2-sec. reinforcement and a single peck on the nonmatching stimulus resulted in a 2-sec. blackout period. Hence, Condition I corresponds to the intertrial interference paradigm. However, one important difference exists between Condition I in the present experiment and the interference conditions in Exps. I and II. In the previous

Table 4

The types of trials used in Exp. III

Color Combination	Condition I	II	III	IV	V
A	G G+R B B+G	G G+ B B+G	4" G+ B B+G	G 2" B B+G	B B+G
B	R GR+ B B+R	R R+ B B+R	4" R+ B B+R	R 2" B B+R	B B+R
C	R R+B G G+R	R R+ G G+R	4" R+ G G+R	R 2" G G+R	G G+R
D	B B+R G BG+	B B+ G BG+	4" B+ G BG+	B 2" G BG+	G BG+
E	B B+G R BR+	B B+ R BR+	4" B+ R BR+	B 2" R BR+	R BR+
F	G G+B R GR+	G G+ R GR+	4" G+ R GR+	G 2" R GR+	R GR+

experiments, the incorrect color on T1 became the correct color on T2, while in the present experiment, the incorrect color on T1 did not appear on the T2 retention test. Thus, any inhibition which was built up to the incorrect color on T1 did not affect the magnitude of the interference effect on T2. In Condition II, a sample stimulus was presented and followed immediately by the illumination of 1 side key with the matching color, while the other key remained dark. A single peck on the illuminated side key resulted in a 2-sec. reinforcement. In Condition III, no sample stimulus was presented; rather, the center key remained dark during the normal sample presentation period. Immediately following this period, 1 side key was illuminated and the other side key remained dark. A single peck on the illuminated side key resulted in a 2-sec. reinforcement. In Condition IV, a sample stimulus was presented, but both side keys remained dark and no reinforcement was presented. Hence, Condition IV corresponds to the intratrial interference paradigm. In 3 of the interference conditions (I, II, and III), T2 immediately followed the 2-sec. reinforcement or the 2-sec. blackout following the side response on T1. In Condition IV, a 2-sec. blackout immediately followed the termination of the T1 sample stimulus; T2 immediately followed this 2-sec. blackout period. In Condition V, no T1 was presented and T2 occurred in isolation. Hence, Condition V was the normal control condition.

A total of 240 different types of trials were used (6 color combinations x 5 conditions x 2 positions of the correct side key on T2 x 4 delays on T2 = 240). In Conditions I, II, and III, the position of the correct side key on T1 was randomly determined. That is, on half of the trials the same position was correct on T1 and on T2, while on the other half of the trials, opposite positions were correct on T1 and on T2. A total of 6 different trial sequences, of 40 trials each, were used. Of these 40 trials per sequence, 8 trials were drawn from each of the 5 conditions, 2 trials from each of the 4 delays within a condition. On each sequence, within each condition, [illegible] of the color combinations appeared once and 2 of the color combinations appeared twice. Each bird received each of the 6 trial sequences and each of the 240 different trials once in an 8-day block. All other aspects of the procedure were the same as in Exp. I.

Results and Discussion

In Fig. 11, each interference condition retention function is individually compared with the Control Condition retention function. Each point in Fig. 11 is based on 360 observations (36 observations per bird x 10 birds = 360). The Control Condition showed a lower level of T2 retention across delays in the present experiment than in Exps. I and II. In addition, the lower level of T2 retention in the Control Condition was more pronounced at the short delays (0 and 2 sec.) than at the long delays (6 and 10 sec.). Thus, in the Control Condition, the rate of retention loss as a function of delays was slower in the present experiment than in the previous experiments. The reason for the lower level of T2 retention and the slower rate of T2 forgetting is unclear.

Each Interference Condition had a higher percentage of correct T2 responses at the 0-sec. delay, and a lower percentage at the 6- and 10-sec. delays than the Control Condition. At the 2-sec. delay,

Figure 11. An individual comparison between each of the 4 Interference Condition retention functions and the Control Condition retention function in Exp. III.

conditions and 1 control condition. In the 1 presentation interference condition, T1 was presented once and the side key choice on T1 introduced the ITI. Following the ITI, T2 was presented. In the 2 presentations interference condition, T1 was presented twice in succession. The second T1 presentation immediately followed the 2-sec. reinforcement or the 2-sec. blackout following the side key choice on the first T1 presentation. Following the side key choice on the second T1 presentation, the ITI was introduced. Following the ITI, T2 was presented. In both interference conditions, the correct color on T1 became the incorrect color on T2, while the incorrect color on T1 did not appear on T2. In the Control Condition, T1 was not presented and T2 occurred in isolation.

A total of 96 different trials were used (4 color combinations x 2 positions of the correct side key on T2 x 4 delays on T2 x 3 conditions = 96). Three trial sequences of 32 trials each were constructed. Each sequence consisted of 10 trials from 1 of the conditions and 11 trials from each of the other 2 conditions.

Three ITIs were employed; 2, 5, and 10 sec. The ITI factor was manipulated between days. Each bird received each of the 3 trial sequences paired with each of the 3 ITIs once in a 9-day block of days. The experiment was run for 4 blocks (36 days). All other aspects of the procedure were the same as in Exp. I.

Results and Discussion

Retention curves for the 1 Presentation and 2 Presentations Conditions at each of the 3 ITIs are shown in Fig. 12. The Control

Conditions I and III were slightly superior to the Control, while Conditions II and IV were inferior to the Control. In Condition I, PI seems to be operating over the first 6 sec., since the rate of forgetting was faster than in the Control Condition. In Condition II, the rate of forgetting of T2 was faster than in the Control Condition over the first 2 sec., and then slower over the next 8 sec. Therefore, PI may be operating over the first 2 sec. in Condition II. In Condition III, the rate of T2 forgetting differed very little from the Control; thus, PI was not evident. In Condition IV, T2 was forgotten more rapidly than in the Control Condition over the first 2 sec., then the rates of forgetting were about equal over the next 8 sec. Therefore, PI may be operating over the first 2-sec. of T2 delay in both Conditions II and IV and over the first 6-sec. of T2 delay in Condition I.

A Ss x Delay x Conditions (I, II, III, IV, and V) x Blocks of Days ANOVA was performed on the data presented in Fig. 11. The only main effect to reach significance was that of delay, $p < .001$. Two of the interaction terms reached significance, the Delay x Conditions interaction and the Delay x Conditions x Blocks of Days interaction, $p < .05$ in both cases (see Appendix XXIII). The Delay x Conditions interaction was produced by the differential rates of T2 forgetting as a function of conditions. The Delay x Conditions x Blocks of Days interaction was probably produced by the rather large amount of variability in the retention functions between blocks.

To further examine the effect of the 4 Interference Conditions on T2 retention, separate ANOVAs were performed comparing each of the Interference Conditions with the Control Condition. The Control Condition (V) versus the Intertrial Condition (I) ANOVA, revealed a significant effect of delay, $p < .001$, and 2 significant interactions, Delay x Conditions and Delay x Conditions x Blocks of Days, $p < .05$ in both cases (see Appendix XXIV). Thus, Condition I did reliably alter the course of T2 forgetting, with a PI effect evident across the first 6-sec. of T2 delay. In both the Control Condition (V) versus the Sample Plus 1 Side Key Positive Condition (II) and the Control versus the 4 Side Key Positive Condition (III) ANOVAs, the only significant main effect was that of delay, $p < .001$ in both cases. None of the interaction terms, in either ANOVA, reached significance (see Appendices XXV and XXVI). On the basis of these ANOVAs, neither Condition II nor Condition III demonstrated an interference effect; neither Condition produced a competition effect or a PI effect. The Control versus Intratrial Condition (IV) ANOVA revealed a signficant main effect of delay, $p < .001$, and a significant Delay x Blocks of Days interaction, $p < .05$ (see Appendix XXVII). On the basis of these ANOVAs, it can be concluded that Condition I demonstrated a reliable PI effect over the first 6-sec. of T2 delay, while neither Conditions II, III, or IV demonstrated any type of interference effect across T2 delays.

Although the ANOVAs revealed that neither Conditions II, III, or IV reliably altered the rate of T2 forgetting across the entire retention interval, it is nevertheless possible that faster T2 forgetting was produced in these conditions, but over a more restricted portion of the retention interval. To evaluate this possibility, retention loss scores, shorter delay percentage minus longer delay percentage, were computed for each of the 3 portions of the retention interval for each condition. The retention loss scores are shown in Table 5. All 4 of the Interference Conditions showed a greater retention loss from 0 to 2 sec. (i.e., faster rate of T2 forgetting) than did the Control Condition. From 2 to 6 sec., 3 of the Interference Conditions showed a greater retention loss than did the Control Condition, while from 6 to 10 sec., the Control Condition showed the greatest loss in retention.

To test the statistical reliability of the greater retention loss, from 0 to 2 sec., in Conditions I, II, and IV than in Condition V, each of the 3 Interference Conditions was compared with the Control Condition by *t*-tests. The rate of retention loss from 0 to 2 sec. was not faster in either Conditions I, II, or IV than in Condition V, $p > .1$, $p > .05$, and $p > .1$, respectively (see Appendix XXVIII). Thus, none of the Interference Conditions demonstrated a reliable PI effect over just the first 2-sec. of T2 delay. In addition, *t*-tests were also performed comparing the Interference Conditions which showed greater retention loss than did the Control Condition from both 0 to 2 sec. and from 2 to 6 sec. (Conditions I, III, and IV) with the Control Condition. Condition I demonstrated a reliable PI effect over the first 6 sec., $p < .01$, while neither Condition III nor IV demonstrated a reliable PI effect over the first 6 sec., $p > .05$ and $p > .1$, respectively (see Appendix XXVIII). Thus, these additional statistical analyses did not alter the main conclusion drawn from the present experiment, the only condition which demonstrated any type

Table 5

Retention loss scores, shorter delay percentage minus longer delay percentage, as a function delay and conditions in Exp. III

	Retention Interval		
Condition	0 to 2 sec.	2 to 6 sec.	6 to 10 sec.
I	13.8	17.2	-2.3
II	19.9	-1.4	5.2
III	9.4	9.7	5.2
IV	16.3	5.8	3.8
V	8.5	4.4	7.2

Condition I: Intertrial interference (sample plus correct and incorrect side keys).

Condition II: Sample plus correct side key (no incorrect side key).

Condition III: Correct side key (no sample and no incorrect side key).

Condition IV: Sample stimulus (no correct or incorrect side key).

Condition V: Control (no T1).

of interference effect was Condition I, which produced a PI effect across the first 6-sec. of T2 delay. It may be concluded that the interfering item must be a complete trial (as in Condition I) to produce PI in pigeon STM, at least for the set of parameters employed in the present experiment.

Unfortunately, the present experiment did not answer the question of whether the intertrial and intratrial interference paradigms differ qualitatively with respect to the type of interference effect produced. That is, given that an interference effect is produced, does the intertrial paradigm always produce a PI type of interference effect and the intratrial paradigm always produce a competition type of interference effect? This question must be answered to allow the theoretical analysis of interference effects in pigeon STM to progress.

Whether or not the intertrial and intratrial interference paradigms differ qualitatively, they do differ quantitatively. A prior complete trial provides a far more potent source of interference than does a prior stimulus occurring on the same trial as the to-be-remembered event.

EXPERIMENT IV

The purpose of the fourth experiment was to investigate the effect of varying the time interval between the final T1 presentation and the presentation of T2 (ITI) upon the PI effect in pigeon STM. In human short-term recall memory, PI has been found to decrease as the ITI is increased (Peterson and Gentile, 1965; Cermak, 1970). Loess and Waugh (1967), also investigating PI in human short-term recall memory, concluded that "PI is directly related to the time between items" (p. 459). In addition, they found no evidence of a build up of PI when ITIs of 120 sec. or greater were employed. Recently, Gorfein (1971), Gorfein and Jacobson (1972), and Lang and Gorfein (1973) have shown the effect of ITI upon PI to be the same in human short-term recognition memory as it is in human short-term recall memory. Investigating intratrial interference in pigeon STM, Grant and Roberts (1973) found the level of interference to be inversely related to the length of time separating successive inputs (i.e., S1 and S2). The purpose of the present experiment was to determine whether or not a relationship between the level of PI and the degree of spacing between items, analogous to that found in human STM would be obtained using the intertrial interference paradigm.

Method

Subjects. Same as in Exp. I, II, and III.

Apparatus. Same as in Exp. I, II, and III.

Procedure. Three conditions were employed; 2 interference conditions and 1 control condition. In the 1 presentation interference condition, T1 was presented once and the side key choice on T1 introduced the ITI. Following the ITI, T2 was presented. In the 2 presentations interference condition, T1 was presented twice in succession. The second T1 presentation immediately followed the 2-sec. reinforcement or the 2-sec. blackout following the side key choice on the first T1 presentation. Following the side key choice on the second T1 presentation, the ITI was introduced. Following the ITI, T2 was presented. In both interference conditions, the correct color on T1 became the incorrect color on T2, while the incorrect color on T1 did not appear on T2. In the Control Condition, T1 was not presented and T2 occurred in isolation.

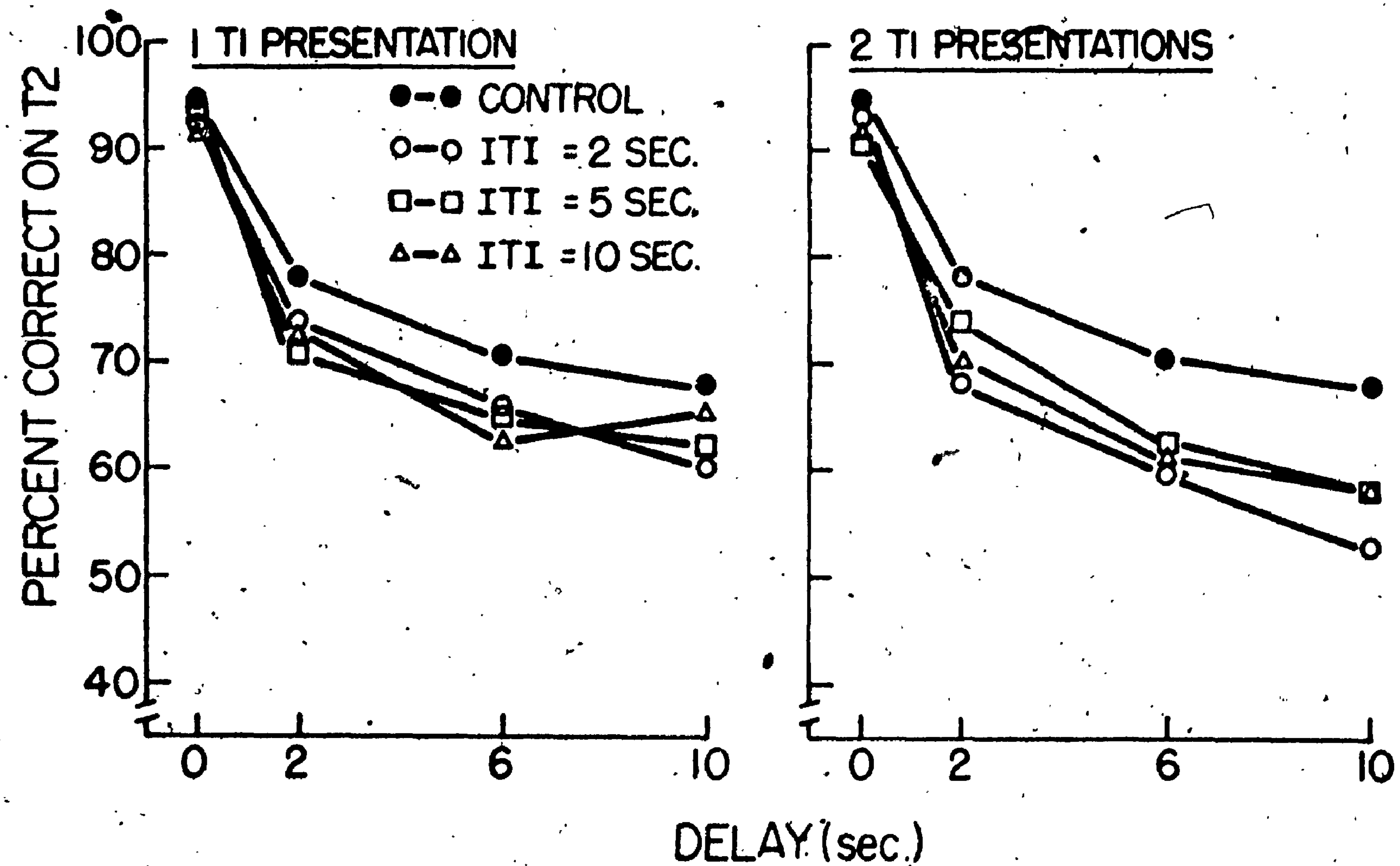
A total of 96 different trials were used (4 color combinations x 2 positions of the correct side key on T2 x 4 delays on T2 x 3 conditions = 96). Three trial sequences of 32 trials each were constructed. Each sequence consisted of 10 trials from 1 of the conditions and 11 trials from each of the other 2 conditions.

Three ITIs were employed; 2, 5, and 10 sec. The ITI factor was manipulated between days. Each bird received each of the 3 trial sequences paired with each of the 3 ITIs once in a 9-day block of days. The experiment was run for 4 blocks (36 days). All other aspects of the procedure were the same as in Exp. I.

Results and Discussion

Retention curves for the 1 Presentation and 2 Presentations Conditions at each of the 3 ITIs are shown in Fig. 12. The Control

Figure 12. Retention curves for the 1 Presentation and 2 Presentations Conditions at each of the 3 ITIs and for the Control Condition in Exp. IV.



1 TI PRESENTATION
2 TI PRESENTATIONS
CONTROL
ITI = 2 SEC.
ITI = 5 SEC.
ITI = 10 SEC.
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

Condition retention curve is also shown in Fig. 12. Each point on the interference curves is based on 320 observations (32 observations per bird x 10 birds = 320) and each point on the control curve is based on 960 observations (96 observations per bird x 10 birds = 960). The 2 Presentations Condition produced a stronger PI effect than the 1 Presentation Condition. Neither of the Interference Conditions was affected by the ITI factor. Increasing the ITI, from 2 to 5 to 10 sec., did not decrease the rate of forgetting of the T2 memory in either the 1 Presentation or 2 Presentations Conditions. Thus, the magnitude of the PI effect was not altered by the ITI factor.

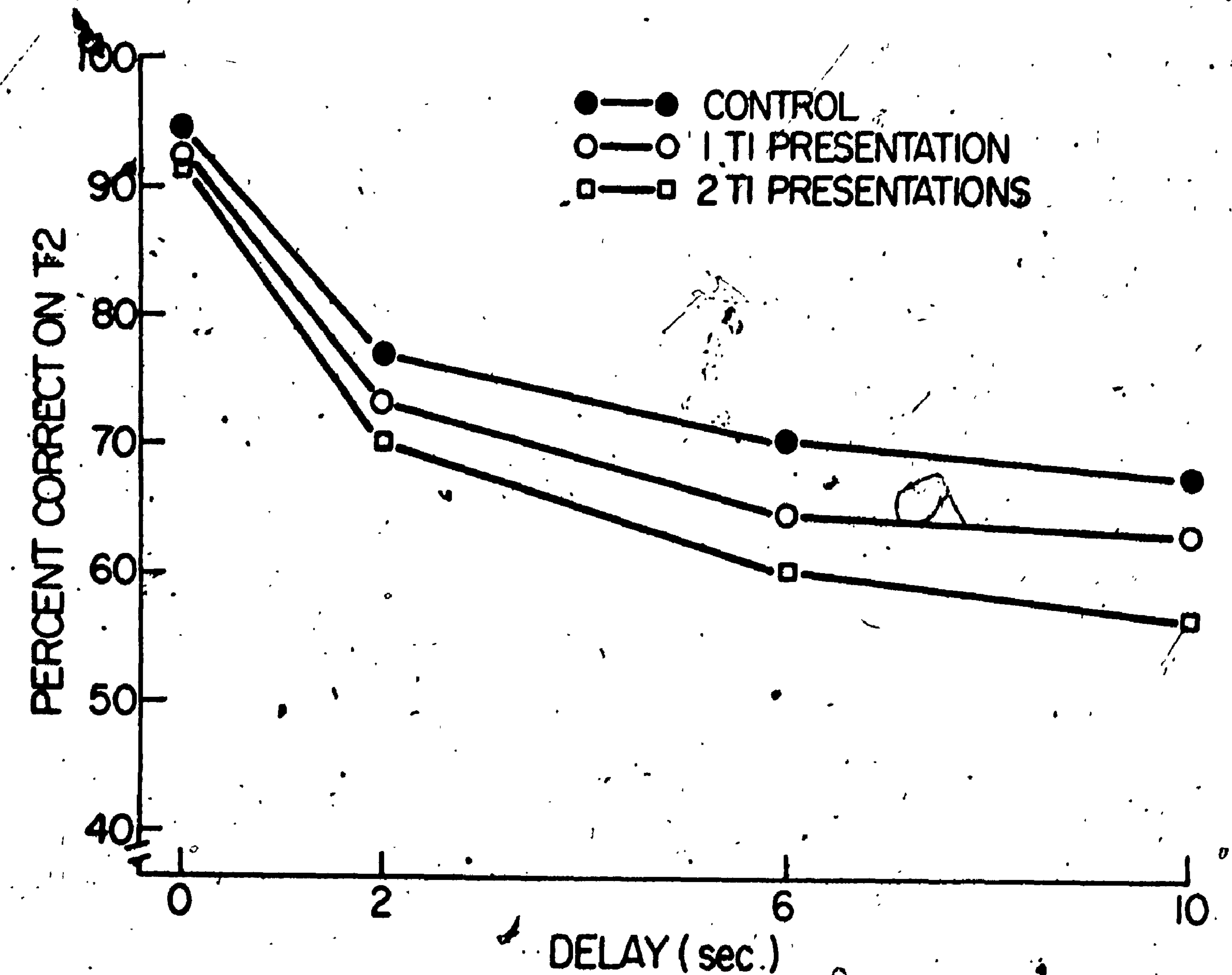
A Ss x Delay x Conditions (Control, 1 Presentation, and 2 Presentations) x ITI x Blocks of Days ANOVA was performed on the data in Fig. 12. (Note: For purposes of this analysis, control trials run on days when the ITI on interference trials was 2-sec. were designated as control-2-sec. ITI trials. Likewise, control trials run on days when the ITI was 5 sec. were designated as control-5-sec. ITI trials and Control trials run on days when the ITI was 10 sec. were designated control-10-sec. ITI trials. Therefore, an ITI effect on interference trials would be indicated by a Conditions x ITI interaction). The ANOVA revealed significant effects of delay, $p < .001$, and of conditions, $p < .01$. The main effects of ITI and of blocks of days were not significant, $p > .05$. None of the interaction terms reached significance (see Appendix XXIX). From this analysis, it can be concluded that the 1 Presentation and 2 Presentations Conditions did produce interference, but the increase in interference with increasing delay was not statistically significant. It can also be concluded that regardless of whether the test item was separated from the interfering item by 2-, 5-, or 10-sec., comparable interference effects were generated.

Since the ITI factor did not alter T2 retention in any of the 3 conditions, the data for the Control, 1 Presentation, and 2 Presentations Conditions was collapsed across the 3 levels of ITI. Retention curves for the 3 conditions, collapsed across ITIs, are presented in Fig. 13. Each point in Fig. 13 is based on 960 observations (96 observations per bird x 10 birds = 960). Both Interference Conditions were inferior to the Control Condition, and the 2 Presentations Condition was inferior to the 1 Presentation Condition. In the 1 Presentation Condition, the magnitude of the interference effect (control percentage minus interference percentage) increased over the first 6-sec. of T2 delay, and then decreased from the 6- to the 10-sec. delay (1.8, 4.6, 6.1, and 4.3 at the 0-, 2-, 6-, and 10-sec. delays, respectively). Thus, a PI effect was obtained over the first 6-sec. of T2 delay in the 1 Presentation Condition. In the 2 Presentations Condition, the magnitude of the interference effect increased over all 4 delays (2.4, 7.2, 9.9, and 11.1 at the 0-, 2-, 6-, and 10-sec. delays, respectively). Thus, a PI effect was obtained over the entire 10-sec. retention interval in the 2 Presentations Condition.

A Ss x Delay x Conditions ANOVA was performed on the data in Fig. 13. This ANOVA revealed significant effects of conditions, $p < .01$, and of delay, $p < .001$. The Delay x Conditions interaction was not significant, $p > .05$ (see Appendix XXX). Separate Ss x Delay x Conditions ANOVAs were performed comparing the Control and 1 Presentation Conditions and comparing the Control and 2 Presentations Conditions. In both analyses the Delay x Conditions interaction

A Ss x Delay x Conditions x Blocks of Days ANOVA was also performed comparing the Control and 2 Presentations Conditions at each ITI. At the 2-sec. ITI, the main effects of delay and of conditions were significant, $p < .001$ and $p < .05$ respectively. None of the interaction terms reached significance (see Appendix XXXVIII). However, as indicated in Table 6, at the 2-sec. ITI the magnitude of the interference effect produced by the 2 Presentations of T1 Condition increased over the first 6-sec. of T2 delay. Retention loss scores, shorter delay percentage minus longer delay percentage, were computed for the Control and 2 Presentations Conditions from the 0-sec. delay to the 6-sec. delay. The mean retention loss, in percentage terms, from the 0- to the 6-sec. delay was 26.9 in the 2 Presentations Condition and 15.6 in the Control Condition; a difference in retention loss of 11.3 percentage points. By t-test, this difference was found to be significant, $p < .05$ (see Appendix XXXIX). Therefore, the 2 Presentations Condition produced a PI effect over the first 6-sec. of T2 delay at the 2-sec. ITI. At the 20-sec. ITI, the only significant term was the main effect of delay, $p < .001$ (see Appendix XL). However, as indicated in Table 6, PI may have been produced over the first 2 sec. in the 2 Presentations Condition at the 20-sec. ITI. Retention loss scores from the 0- to the 2-sec. delay were calculated for the Control and 2 Presentations Conditions at the 20-sec. ITI. The retention loss, in percentage terms, was 19.4 in the 2 Presentations Condition and 11.3 in the Control Condition; a difference of 8.1 percentage points. By t-test, this difference was found to be significant, $p < .01$ (see Appendix XXXIX). Therefore, the 2

Figure 13. Retention curves for the Control, 1 Presentation, and 2 Presentations Conditions, collapsed across ITIs, in Exp. IV.


CONTROL
1 TI PRESENTATION
2 TI PRESENTATIONS
PERCENT CORRECT ON T2
100
90
80
70
60
50
40
0
2
6
10
DELAY (sec.)

failed to reach significance, $p > .05$ in both cases (see Appendices XXXI and XXXII). These analyses revealed that in neither the 1 Presentation Condition nor the 2 Presentations Condition was the increase in the magnitude of the interference effect across the 3 portions of the retention interval (0 to 2, 2 to 6, and 6 to 10) statistically reliable.

However, Fig. 13 indicates that the conditions factor had a greater effect upon T2 performance at the 2-, 6-, and 10-sec. delays than at the 0-sec. delay. To evaluate the statistical reliability of this effect, separate one-way ANOVAs were performed comparing each of the 3 conditions at each of the 4 delays. The effect of conditions was not significant at the 0-sec. delay, $p > .05$, but was significant at the 2-, 6-, and 10-sec. delays, $p < .05$ in all 3 cases (see Appendix XXXIII). Thus, no interference was obtained on the immediate test, but significant interference was demonstrated at the longer retention intervals. Therefore, PI was demonstrated since the conditions did not differ in the degree of original learning of T2 (as measured by the 0-sec. delay), but did differ in the retention of T2 (as measured by the 2-, 6-, and 10-sec. delays).

On the basis of the results of the present experiment, it can be concluded that increasing the temporal separation between the interfering item and the test item, from 2 to 5 to 10 sec., did not alter the magnitude of the PI effect. However, it is possible that the degree of temporal separation between the interfering item and the test item would affect the magnitude of the PI effect obtained in pigeon STM if longer ITIs were employed. To test this possibility, the fifth experiment was conducted.

EXPERIMENT V

Exp. IV, employing ITIs of 2, 5, and 10 sec., found that the PI effect in pigeon STM was not affected by the degree of temporal separation between the interfering item and the test item. The purpose of the fifth experiment was to determine whether the PI effect would decrease as a function of increasing ITI if ITIs longer than those used in Exp. IV were employed.

Method

Subjects. Same as in Exp. I, II, III, and IV.

Apparatus. Same as in Exp. I, II, III, and IV.

Procedure. The same trial sequences and procedure were used in the present experiment as were used in the previous experiment, with 3 exceptions. First, in the previous experiment the incorrect color on T1 did not appear on T2, while in the present experiment the incorrect color on T1 became the correct color on T2. Thus, correct and incorrect colors on T1 were reversed on T2 (i.e., correct became incorrect and incorrect became correct). This change in procedure was made in an attempt to demonstrate a more powerful PI effect at the 2-sec. ITI than was demonstrated in the previous experiment. Second, the intercondition interval, which occurred following all T2 trials, was increased from 45 to 60 sec. Third, rather than employing ITIs of 2, 5, and 10 sec., ITIs of 2, 20, and 40 sec. were employed. Control trials run on days when the ITI on interference trials was 2 sec. were designated as control-2-sec. ITI trials.

Likewise, control trials run on 20-sec. ITI days were designated as control-20-sec. ITI trials and control trials run on 40-sec. ITI days were designated as control-40-sec. ITI trials.

Results and Discussion

The data of interest were the magnitude of the interference effect across delays as a function of ITI. However, if this measure is to accurately reflect the effect of ITI upon forgetting in the Interference Conditions, it is necessary to demonstrate that retention in the Control Condition was not affected by the ITI factor. Therefore, a Ss x Delay x ITI x Blocks of Days ANOVA was performed on the percentage of correct T2 responses in the Control Condition. The only significant term was the main effect of delay, $p < .001$; the effect of ITI was not significant, $F = .05$ (see Appendix XXXIV). On the basis of this analysis, it can be concluded that any changes in the magnitude of the interference effect as a function of ITI reflect the effect of ITI upon forgetting in the Interference Condition.

The magnitude of the interference effect (control percentage minus interference percentage) generated by each Interference Condition at each delay within each ITI is shown in Table 6. Examining the 1 Presentation of T1 interference effect, the ITI factor did not affect performance at the 0-sec. retention interval, but strongly influenced retention at the 2-, 6-, and 10-sec. retention intervals. This finding indicated that the effect of ITI was upon the rate of T2 forgetting, rather than upon the degree of original learning of T2.

Table 6

Magnitude of the interference effect, control percentage minus interference percentage, as a function of Interference Condition, delay, and ITI in Exp. V

1 Presentation of T1 Condition

ITI (sec.)	Delay (sec.) 0	2	6	10
2	.6	13.1	17.5	15.0
20	-1.3	3.8	2.5	2.5
40	0	1.9	3.1	-1.3

2 Presentations of T1 Condition

ITI (sec.)	Delay (sec.) 0	2	6	10
2	5.0	11.3	16.3	4.4
20	0	8.1	1.9	3.8
40	5.0	6.9	8.8	3.8

At the 2-sec. ITI, a large interference effect was obtained at the 2-, 6-, and 10-sec. retention intervals. In addition, the magnitude of the interference effect increased across the first 6-sec. of T2 delay and then decreased slightly at the 10-sec. delay. At the 20- and 40-sec. ITIs, on the other hand, negligible interference was obtained at these 3 retention intervals. Moreover, there was no evidence to suggest that PI was operating when ITIs of 20 or 40 sec. were employed. Examining the 2 Presentations of T1 interference effect, the 2-sec. ITI produced a PI effect over the first 6-sec. of T2 delay. At the 20-sec. ITI, PI was evident only over the first 2 sec. of T2 delay. At the 40-sec. ITI, there was little evidence to suggest the operation of PI; however, a relatively constant interference effect does seem to be operating.

A Ss x Delay x Conditions x Blocks of Days ANOVA was performed comparing the Control and 1 Presentation Conditions at each of the 3 ITIs. At the 2-sec. ITI, a significant effect of delay and of conditions, $p < .001$ in both cases, was obtained. The Delay x Conditions interaction was also significant, $p < .05$ (see Appendix XXXV). At both the 20- and 40-sec. ITIs, the only significant main effect was that of delay, $p < .001$ in both cases. None of the interaction terms, in either analysis, reach significance (see Appendices XXXVI and XXXVII). On the basis of these analyses, it can be concluded that PI was obtained when a 2-sec. ITI was employed, but not when either a 20- or 40-sec. ITI was employed. Increasing the temporal separation between the interfering item and the test item from 2 to 20 sec. eliminated the PI effect.

A $\underline{S}s$ x Delay x Conditions x Blocks of Days ANOVA was also performed comparing the Control and 2 Presentations Conditions at each ITI. At the 2-sec. ITI, the main effects of delay and of conditions were significant, $p < .001$ and $p < .05$ respectively. None of the interaction terms reached significance (see Appendix XXXVIII). However, as indicated in Table 6, at the 2-sec. ITI the magnitude of the interference effect produced by the 2 Presentations of T1 Condition increased over the first 6-sec. of T2 delay. Retention loss scores, shorter delay percentage minus longer delay percentage, were computed for the Control and 2 Presentations Conditions from the 0-sec. delay to the 6-sec. delay. The mean retention loss, in percentage terms, from the 0- to the 6-sec. delay was 26.9 in the 2 Presentations Condition and 15.6 in the Control Condition; a difference in retention loss of 11.3 percentage points. By $\underline{t}$-test, this difference was found to be significant, $p < .05$ (see Appendix XXXIX). Therefore, the 2 Presentations Condition produced a PI effect over the first 6-sec. of T2 delay at the 2-sec. ITI. At the 20-sec. ITI, the only significant term was the main effect of delay, $p < .001$ (see Appendix XL). However, as indicated in Table 6, PI may have been produced over the first 2 sec. in the 2 Presentations Condition at the 20-sec. ITI. Retention loss scores from the 0- to the 2-sec. delay were calculated for the Control and 2 Presentations Conditions at the 20-sec. ITI. The retention loss, in percentage terms, was 19.4 in the 2 Presentations Condition and 11.3 in the Control Condition; a difference of 8.1 percentage points. By $\underline{t}$-test, this difference was found to be significant, $p < .01$ (see Appendix XXXIX). Therefore, the 2

Presentations Condition produced a PI effect over the first 2-sec. of T2 delay at the 20-sec. ITI. At the 40-sec. ITI, the only significant terms were the main effects of delay and of conditions, $p < .001$ and $p < .05$ respectively (see Appendix XLI). Therefore, the 2 Presentations Condition produced an interference effect, but not a PI effect, at the 40-sec. ITI. The reason for obtaining this last result is totally unclear.

On the basis of the results of the present experiment, it can be concluded that the degree of temporal separation between the interfering item and the test item does affect PI in pigeon STM. When the interfering item was presented once, the PI effect was eliminated by a temporal separation of either 20 or 40 sec. When the interfering item was presented twice, a temporal separation of 20 sec. resulted in the PI effect being restricted to a smaller, earlier portion of the retention interval. Increasing the temporal separation to 40 sec. resulted in the PI effect being eliminated; however, a competition type of interference effect was produced. Perhaps the best interpretation of this latter finding is that it is an instance of a type I error; that is, that no difference actually exists between the Control and 2 Presentations Conditions at the 40-sec. ITI.

GENERAL DISCUSSION

Five experiments were performed to investigate the effect of prior learning upon the retention of subsequent learning in pigeon STM. The general paradigm employed was termed the intertrial interference paradigm. This paradigm involved two basic conditions; an Experimental (Interference) Condition and a Control Condition. In the Experimental Condition, two DMTS trials, T1 and T2, were presented in immediate succession. Correct and incorrect colors on T1 were reversed on T2; the correct color on T1 became the incorrect on T2 and the incorrect color on T1 became the correct color on T2. In the Control Condition, T1 was not presented and T2 occurred in isolation. The comparison of interest involved the percentage of correct T2 responses as a function of T2 delay in the Experimental and Control Conditions.

Five main findings emerged from Exp. I. First, the presence of a prior, conflicting memory, T1, increased the rate at which a subsequent memory, T2, was forgotten over the first 6-sec. of the retention interval. Thus, a PI effect was obtained over the first 6-sec. of T2 delay. Second, PI over the first 6-sec. of T2 delay was obtained when T1 was presented either one or six times before T2 was presented, but when T1 was presented four times, PI was evident only over the first 2-sec. of T2 delay. The reason for not obtaining a PI effect over the first 6-sec. of T2 delay when T1 was presented four times was unclear. Third, when T1 was presented either one or six times, T2 retention was higher at the 10-sec. than at the 6-sec. delay. Fourth, increasing the number of times T1 was presented, from one to six, increased the interference effect by a relatively constant amount across T2 delays. Fifth, the method of determining the position of the correct side key on each T1 presentation had a relatively small effect upon T2 retention.

The second experiment was designed to determine whether PI in pigeon STM was produced by encoding and/or storage failure or by the competition of conflicting memories at retrieval. Two main results were obtained. First, significant PI was obtained whether the correct color on T1 became the incorrect color on T2 or whether the incorrect color on T1 became the correct color on T2. Second, a slight, and nonsignificant, facilitation of T2 retention occurred when either the correct and incorrect colors on T1 did not appear on T2, or when the correct color on T1 did not appear on T2 and the incorrect color on T1 remained incorrect on T2. These two findings eliminated the encoding and/or storage failure explanation of PI effects in pigeon STM. On the other hand, the results provide strong support for the notion that PI in pigeon STM results from the competition of conflicting memories at the time of retrieval.

The third experiment was designed to determine the effect of using various types of events as the T1 or interfering item. Four T1 events were used; a complete DMTS trial (intertrial interference paradigm), the sample stimulus and the correct side key, just the correct side key, and just the sample stimulus (intratrial interference paradigm). The only condition which produced a significant interference effect was the intertrial interference condition; in which a complete DMTS trial served as the T1 event. That condition produced a significant PI effect over the first 6-sec. of T2 delay. None of the other three conditions differed significantly from the control. It was concluded that the types of events used as T1 differed quantitatively with respect to the amount of interference they produced; a prior complete DMTS trial represents a more potent source of interference than any of the other types of T1 events. From the results of Exp. III, it could not be determined if the interference conditions differed qualitatively with respect to the type of interference effect which they produce.

The fourth experiment was designed to investigate the effect of separating the interfering event from the to-be-remembered event by either 2, 5, or 10 sec. It was found that the magnitude of the PI effect was not affected by whether the interfering trial terminated 2, 5, or 10 sec. before the onset of the to-be-remembered trial. However, Exp. V demonstrated that when the interfering item was presented once, the PI effect was eliminated when the temporal separation between the interfering and to-be-remembered events was either 20 or 40 sec. When the interfering memory was based on two presentations of T1, the PI effect was restricted to a smaller, earlier portion of the retention interval when the temporal separation was 20 sec. At the 40 sec. temporal separation value, no PI was obtained; however, a small, relatively constant interference effect across T2 delays was produced.

The main finding to emerge from the experimental series was that PI was demonstrated in pigeon STM. Since PI has been found in primate and human STM and in rat LTM, the demonstration of PI in pigeon STM adds experimental support to the position that conflicting memories interact in the same manner regardless of species. The present findings add weight to the contention that the same basic memorial processes may operate in the pigeon, rat, primate, and human. However, one important difference between PI in pigeon and human STM did emerge. As was pointed out in the introduction, studies of PI in human short-term recognition memory have found that PI is unrelated to the type of distractor (i.e., incorrect item(s)) employed at the time of test. That is, PI is obtained both when previously presented items are used as distractors and when new items (i.e., items not previously presented during the experiment) are used as distractors. On the other hand, Exp. II demonstrated that the type of incorrect item employed on the test was critical to producing PI in pigeon STM. PI was produced when the correct T1 item served as the incorrect T2 item; but no PI was produced when an item not presented on T1 served as the incorrect item on T2. The human data support the contention that PI is not produced by the competition of conflicting memories at retrieval; rather, PI may be produced by encoding and/or storage processes. The pigeon data support the contention that PI is produced by competition between conflicting memories at retrieval, and not by encoding and/or storage processes. Thus, although PI has been obtained in both human and pigeon STM, the mechanisms responsible for producing PI in the two species may differ.

In general, the present experiments found that the magnitude of the interference effect increased across the first 6-sec. of T2 delay and decreased at the 10-sec. delay. However, in some cases, increasing interference was obtained only over the first 2-sec. of the retention interval; in other cases, increasing interference was obtained over the entire 10-sec. retention interval. It may be useful to consider how some of the theoretical interpretations of interference effects might account for these findings. Three theoretical interpretations will be considered; the Keppel and Underwood extinction and spontaneous recovery model, the Spear attribute memory model, and the Grant and Roberts independence and competition model.

Both the Keppel and Underwood model and the Spear model predict increasing interference with increasing delay. Thus, both models can account for the present findings over the first 6-sec. of the retention interval. To account for the decrease in the magnitude of the interference effect over the final 4-sec. of the retention interval, both models would need to add an additional assumption. Perhaps the most reasonable assumption would be to assume that at the time of the 10-sec. delay retention test, the T1 memory had been lost from memory on some proportion of the trials. This assumption seems plausible since, at the time of the 10-sec. delay retention test on T2, the T1 trial terminated at least 16 sec. previously. In fact, T1 probably terminated considerably longer than 16 sec. before the 10-sec. delay test on T2. Two factors contribute to the lengthening of the T1 decay period. First, there is the latency period before S pecks the white center key to initiate T2. Second, there is the latency period before S makes the side key choice on T2. These two latency periods could combine to produce several seconds of additional T1 decay time. It seems reasonable to propose, on the basis of the rapid forgetting found in DMTS by several investigators, that a memory which has decayed for more than 16 sec. will generally have a strength which approaches 0.

This assumption could be incorporated into both the Keppel and Underwood model and the Spear model. Keppel and Underwood might propose that the T1 spontaneously recovers over the first 6-sec. of T2 delay; reaching an asymptotic recovery strength at the 6-sec. delay. Over the last 4-sec. of the retention interval (i.e., 6 to 10 sec.), the T1 memory undergoes a period of rapid loss of strength. Therefore, one would expect increasing interference over the first 6-sec. of the retention interval and decreased interference at the 10-sec. retention test. On the other hand, Spear might propose that during the T2 retention interval, both the T1 and T2 memories lose strength. In addition, as time passes since the establishment of the T2 memory, the proportion of retrieval cues available for retrieving the T1 memory increases. However, at the 10-sec. retention test, although the proportion of cues available for retrieving the T1 memory has continued to increase, it cannot be retrieved on those trials on which it is no longer present in the memory system. Therefore, one would expect increasing interference over the first 6-sec. of the retention interval and decreased interference at the 10-sec. retention test.

The final theoretical interpretation of interference effects to be considered is the Grant and Roberts independence and competition model. Although the model was developed to account for a relatively constant interference effect across delays, the model also predicts increasing interference as a function of delay under certain conditions. This is the case since the model holds that interference effects are the product of competition between conflicting memory traces. The magnitude of the interference effect is a direct function of the degree of overlap between the trace strength distributions of the conflicting memories (we may ignore the effect of the recency factor for the present). Therefore, when two conflicting traces begin to decay at approximately the same point on the negatively accelerated decay function, both traces decay or lose strength at approximately the same rate. Thus, the degree of overlap between the two trace strength distributions remains relatively constant as the retention interval increases. This situation would produce a relatively constant interference effect across delays. On the other hand, when the prior memory has undergone a period of trace decay before the current memory begins to decay, the negatively accelerated decay function results in the prior memory losing trace strength less rapidly than the current memory as the retention interval increases. Therefore, as the delay following the establishment of the current memory increases, the degree of overlap between the two trace strength distributions also increases, resulting in increasing interference with increasing delay. To account for the decrease in the magnitude of the interference effect at the 10-sec. delay, one could again invoke the assumption that the T1 memory had been lost from STM on the majority of trials.

Recently, Gleitman (1971) and D'Amato (1972) have emphasized the role of temporal factors in animal memory. They propose that as the retention increases, the animal's ability to discriminate which memory is the more recent progressively declines. Obviously, both theorists would predict increasing interference with increasing delay. However, a model based solely on the animal's ability to make a temporal discrimination does not seem adequate to account for the present results. For example, how would such a model handle the finding of decreased interference at the 10-sec. delay? Or, how would such a model account for the effect of increasing the number of times T1 was presented upon the interference effect? In addition, several studies of pigeon STM (Roberts, 1972; Grant and Roberts, 1973; Roberts and Grant, 1974) have clearly demonstrated the theoretical value of postulating some type of memory strength mechanism. This is not to deny that temporal factors operate in pigeon STM, but rather that temporal factors alone do not provide an adequate theoretical base for explaining pigeon STM. Temporal factors are most probably involved in producing PI in pigeon STM, as they are in producing competition in pigeon STM (Roberts and Grant, 1974), but not to the exclusion of memory strength factors.

Incorporating temporal discrimination factors into the Grant and Roberts' competition model provides an explanation for the change in the interference effect across experiments. In Exp. I, the 1 presentation of T1 condition produced more interference at the 0-, 2-, and 6-sec. delays than was produced in subsequent experiments at these delays, particularly Exps. IV and V. In addition, the 1-presentation condition produced no interference at the 10-sec.

delay in Exp. I, but did produce interference at this delay in subsequent experiments, partitularly Exp. V. This finding can be accounted for by postulating changes in the trace strength of the T1 memory and changes in the animal's ability to make a temporal discrimination as a function of training. To account for the increasing interference at the 10-sec. delay across experiments, it could be postulated that the rate of T1 forgetting decreased with training. Therefore, a stronger interfering memory would be present at the time of the 10-sec. delay in later experiments. To account for the decreasing interference at the 0-, 2-, and 6-sec. delays across experiments, it could be postulated that the animal's ability to discriminate the more recent memory improves with training. Therefore, less interference would be expected in later experiments.

One major question regarding interference effects in pigeon STM is whether or not the type of interference effect produced in the intertrial interference paradigm differs qualitatively from the type of interference effect produced in the intratrial interference paradigm. That is, does the memory of a prior complete trial compete with a later memory in a fundamentally different way than the way in which a prior stimulus event competes. If this question is answered in the affirmative, two sets of theoretical laws would need to be postulated, one based on the memory of stimuli and the other based on the memory of complete trials. On the other hand, the Grant and Roberts' model predicts that the type of interference effect produced is determined by the amount of decay of the interfering memory which occurs before the test memory begins to decay. If the interfering memory decays very little before the test memory begins to decay, a competition effect results. On the other hand, if the interfering memory has undergone a considerable amount of decay before the test memory begins to decay, a PI effect results. Thus, it should be possible to produce competition and PI in both the intratrial and intertrial interference paradigms. A research project is currently in progress which is directed at determining whether or not a PI effect can be demonstrated using the intratrial interference paradigm.

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APPENDIX

APPENDIX I

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and Interference Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	8011.87/106.79	75.02 ***
C = Conditions	1, 9	8997.45/288.02	31.24 ***
D = Blocks	1, 9	55.71/76.45	.73
B x C	3, 27	402.48/74.35	5.41 **
B x D	3, 27	64.37/61.89	1.04
C x D	1, 9	120.36/57.01	2.11
B x C x D	3, 27	3.41/120.73	.03

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX II

Summary of Analysis of Variance on the percentage of correct T2 responses, excluding the 10-sec. delay, in the Control and Interference Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	2, 18	9085.95/78.25	116.12 ***
C = Conditions	1, 9	8423.91/194.41	43.33 ***
D = Blocks	1, 9	124.39/46.34	2.69
B x C	2, 18	418.04/58.25	7.18 **
B x D	2, 18	52.56/66.11	.79
C x D	1, 9	102.71/69.32	1.48
B x C x D	2, 18	4.31/92.02	.05

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX III

Summary of Analysis of Variance on the percentage of correct T2 responses in the 1, 4, and 6 presentations of T1 Conditions and the Control Condition in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	256.71/2.29	111.91 ***
C = Conditions	3, 27	83.96/3.95	21.25 ***
D = Blocks	1, 9	.11/1.80	.06
B x C	9, 81	9.98/1.79	5.57 ***
B x D	3, 27	1.75/1.83	.96
C x D	3, 27	2.95/1.22	2.43
B x C x D	9, 81	3.53/1.76	2.01

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX IV

Summary of Analysis of Variance on the percentage of correct T2 responses in the 1 presentation and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	122.19/1.97	62.11 ***
C = Conditions	1, 9	49.51/3.37	14.70 **
D = Blocks	1, 9	3.91/2.18	1.79
B x C	3, 27	13.11/1.19	11.02 ***
B x D	3, 27	2.34/1.58	1.48
C x D	1, 9	.06/.86	.07
B x C x D	3, 27	1.82/2.04	.89

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX V

Summary of Analysis of Variance on the percentage of correct T2 responses, excluding the 10-sec. delay, in the 1 presentation and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	2, 18	154.23/1.42	108.73 ***
C = Conditions	1, 9	64.53/2.14	30.09 ***
D = Blocks	1, 9	4.03/.39	10.47 *
B x C	2, 18	12.13/.86	14.18 ***
B x D	2, 18	3.33/1.29	2.57
C x D	1, 9	.30/1.61	.19
B x C x D	2, 18	2.50/1.70	1.47

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX VI

Summary of Analysis of Variance on the percentage of correct T2 responses in the 4 presentations and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	117.27/2.03	57.71 ***
C = Conditions	1, 9	195.81/6.47	30.25 ***
D = Blocks	1, 9	1.41/1.43	.98
B x C	3, 27	2.76/1.87	1.48
B x D	3, 27	3.62/.84	4.33 *
C x D	1, 9	1.06/1.36	.78
B x C x D	3, 27	1.57/2.36	.67

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX VII

Summary of Analysis of Variance on the percentage of correct T2 responses in the 6 presentations and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	117.34/2.49	46.95 ***
C = Conditions	1, 9	172.23/5.42	31.78 ***
D = Blocks	1, 9	.23/.89	.25
B x C	3, 27	12.14/2.04	5.95 **
B x D	3, 27	2.08/1.59	1.30
C x D	1, 9	7.23/1.45	4.99
B x C x D	3, 27	2.01/2.15	.93

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX VIII

Summary of Analysis of Variance on the percentage of correct T2 responses, excluding the 10-sec. delay, in the 6 presentations and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	2, 18	144.48/2.00	72.14 ***
C = Conditions	1, 9	172.80/3.26	52.96 ***
D = Blocks	1, 9	.53/1.63	.33
B x C	2, 18	11.88/1.92	6.18 **
B x D	2, 18	.51/1.63	.31
C x D	1, 9	3.33/1.39	2.40
B x C x D	2, 18	2.51/1.04	2.42

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX IX

Two-tailed t-tests between selected means in Exp. I.

Comparison	df	t	p
6 presentations, 6-sec. delay versus chance (50%)	9	12.35	$p < .001$
4 presentations, 10-sec. delay versus chance (50%)	9	6.99	$p < .001$
6-sec. versus 10-sec. delay within the 1 presentation level	9	4.84	$p < .001$
6-sec. versus 10-sec. delay within the 6 presentations level	9	4.29	$p < .01$
the magnitude of the interference effect on the immediate retention test (0-sec. delay) versus the magnitude of the interference effect on the delayed retention tests (2, 6, 10 sec. delays) in the 4 presentations condition	9	1.79	$p > .1$
the magnitude of the interference effect on the immediate retention test (0-sec. delay) versus the magnitude of the interference effect on the 2-sec. delayed retention test in the 4 presentations condition	9	2.46	$p < .05$

APPENDIX X

Summary of Analysis of Variance on the percentage of correct T2 responses in the Fixed, Random, and Control Conditions in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	13268.33/157.01	84.51 ***
C = Conditions	2, 18	5545.59/262.56	21.12 ***
D = Blocks	1, 9	48.85/98.86	.49
B x C	6, 54	502.52/135.83	3.70 **
B x D	3, 27	43.93/77.97	.56
C x D	2, 18	441.51/145.64	3.03
B x C x D	6, 54	35.94/138.14	.26

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XI

Two-tailed *t*-tests between the Fixed and Random Conditions at each delay in Exp. I.

Delay	df	*t*	*p*
0 sec.	9	1.12	$p > .1$
2 sec.	9	1.59	$p > .1$
6 sec.	9	4.39	$p < .01$
10 sec.	9	-1.49	$p > .1$

APPENDIX XII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Fixed and Random Conditions within the 1 Presentation of T1 Condition in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	12119.25/177.71	68.19 ***
C = Conditions	1, 9	2246.03/174.28	12.89 **
D = Blocks	1, 9	111.97/249.60	.45
B x C	3, 27	456.32/374.23	1.22
B x D	3, 27	515.99/267.45	1.93
C x D	1, 9	560.66/338.12	1.66
B x C x D	3, 27	378.94/183.43	2.07

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XIII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Fixed and Random Conditions within the 4 Presentations of T1 Condition in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	9851.82/268.93	36.63 ***
C = Conditions	1, 9	15.59/312.65	.05
D = Blocks	1, 9	1.73/198.47	.01
B x C	3, 27	474.09/431.56	1.09
B x D	3, 27	645.19/204.11	3.16 *
C x D	1, 9	1459.87/237.04	6.16 *
B x C x D	3, 27	214.68/226.24	.95

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XIV

Summary of Analysis of Variance on the percentage of correct T2 responses in the Fixed and Random Conditions within the 6 Presentations of T1 Condition in Exp. I.

Source	df	MS/MSerror	F
B = Delay	3, 27	11164.68/357.71	31.21 ***
C = Conditions	1, 9	999.95/232.17	4.31
D = Blocks	1, 9	694.35/135.05	5.14 *
B x C	3, 27	666.60/300.07	2.22
B x D	3, 27	490.69/281.11	1.75
C x D	1, 9	27.76/425.13	.07
B x C x D	3, 27	27.79/404.55	.07

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XV

Two-tailed t-tests between the Fixed and Random Conditions at each delay within each level of T1 presentations in Exp. I.

Condition	Delay	df	t	p
1 Presentation	0 sec.	9	.26	$p > .1$
1 Presentation	2 sec.	9	.44	$p > .1$
1 Presentation	6 sec.	9	3.14	$p < .02$
1 Presentation	10 sec.	9	1.37	$p > .1$
4 Presentations	0 sec.	9	.19	$p > .1$
4 Presentations	2 sec.	9	.53	$p > .1$
4 Presentations	6 sec.	9	1.37	$p > .1$
4 Presentations	10 sec.	9	1.15	$p > .1$
6 Presentations	0 sec.	9	1.07	$p > .1$
6 Presentations	2 sec.	9	.48	$p > .1$
6 Presentations	6 sec.	9	.35	$p > .1$
6 Presentations	10 sec.	9	3.14	$p < .02$

APPENDIX XVI

Summary of Analysis of Variance on the percentage of correct T2 responses in the Sample Present, Sample Absent, and Control Conditions in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	220.31/5.14	42.86 ***
C = Conditions	2, 18	26.71/3.75	7.12 **
D = Blocks	2, 18	4.74/2.59	1.83
B x C	6, 54	5.97/2.32	2.57 *
B x D	6, 54	2.19/2.25	.97
C x D	4, 36	1.25/2.09	.59
B x C x D	12, 108	1.52/1.52	1.00

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XVII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Sample Absent and Control Conditions in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	149.32/4.62	32.33 ***
C = Conditions	1, 9	.02/2.34	.03
D = Blocks	2, 18	1.43/1.99	.72
B x C	3, 27	1.68/1.66	1.01
B x D	6, 54	2.10/1.46	1.44
C x D	2, 18	.15/2.47	.06
B x C x D	6, 54	1.62/1.58	1.02

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XVIII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Sample Present and Control Conditions in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	139.48/3.83	36.45 ***
C = Conditions	1, 9	38.40/4.89	7.85 *
D = Blocks	2, 18	5.40/2.34	2.31
B x C	3, 27	10.94/2.83	3.87 *
B x D	6, 54	1.38/2.45	.56
C x D	2, 18	1.51/2.48	.61
B x C x D	6, 54	1.49/1.63	.92

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XIX

Summary of Analysis of Variance on the percentage of correct T2 responses in the A, B, and C subconditions, and the Control Condition in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	316.74/10.39	30.47 ***
C = Conditions	3, 27	37.28/9.34	3.99 *
D = Blocks	2, 18	2.31/4.70	.49
B x C	9, 81	3.88/3.69	1.05
B x D	6, 54	6.16/3.15	1.95
C x D	6, 54	3.33/5.86	.57
B x C x D	18, 162	1.68/4.45	.38

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XX

Summary of Analysis of Variance on the percentage of correct T2 responses in the A subcondition and Control Condition in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	139.67/7.38	18.92 ***
C = Conditions	1, 9	6.67/3.39	1.96
D = Blocks	2, 18	.72/3.07	.23
B x C	3, 27	5.20/4.41	1.18
B x D	6, 54	1.25/3.27	.38
C x D	2, 18	.62/5.42	.11
B x C x D	6, 54	1.48/3.62	.41

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXI

Summary of Analysis of Variance on the percentage of correct T2 responses in the B subcondition and Control Condition in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	178.77/5.29	33.82 ***
C = Conditions	1, 9	35.27/9.47	3.72
D = Blocks	2, 18	2.12/6.04	.35
B x C	3, 27	3.70/1.94	1.91
B x D	6, 54	3.90/3.49	1.12
C x D	2, 18	2.82/4.79	.59
B x C x D	6, 54	1.93/3.25	.59

*** $\underline{p} < .001$

** $\underline{p} < .01$

* $\underline{p} < .05$

APPENDIX XXII

Summary of Analysis of Variance on the percentage of correct T2 responses in the C subcondition and Control Condition in Exp. II.

Source	df	MS/MSerror	F
B = Delay	3, 27	138.72/5.91	23.47 ***
C = Conditions	1, 9	14.02/6.53	2.15
D = Blocks	2, 18	6.72/3.50	1.92
B x C	3, 27	.65/2.83	.23
B x D	6, 54	2.65/3.09	.86
C x D	2, 18	1.82/4.44	.41
B x C x D	6, 54	2.68/3.43	.78

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXIII

Summary of Analysis of Variance on the percentage of correct T2 responses in Conditions I, II, III, IV, and V in Exp. III.

Source	df	MS/MSerror	F
B = Delay	3, 27	255.73/4.13	61.99 ***
C = Conditions	4, 36	1.64/2.83	.58
D = Blocks	2, 18	1.37/2.64	.52
B x C	12, 108	5.70/2.89	1.97 *
B x D	6, 54	1.45/1.67	.[illegible]6
C x D	8, 72	1.34/2.61	.51
B x C x D	24, 216	3.53/1.97	1.79 *

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXIV

Summary of Analysis of Variance on the percentage of correct T2 responses in the Intertrial (I) and Control (V) Conditions in Exp. III.

Source	df	MS/MSerror	F
B = Delay	3, 27	109.44/3.89	28.15 ***
C = Conditions	1, 9	5.10/3.62	1.41
D = Blocks	2, 18	.68/1.39	.49
B x C	3, 27	12.45/3.02	4.13 *
B x D	6, 54	2.99/1.59	1.88
C x D	2, 18	2.93/1.74	1.68
B x C x D	6, 54	6.59/1.93	3.41 **

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXV

Summary of Analysis of Variance on the percentage of correct T2 responses in the Sample Plus One Side Key Positive (II) and Control (V) Conditions in Exp. III.

Source	df	MS/MSerror	F
B = Delay	3, 27	75.23/2.39	31.39 ***
C = Conditions	1, 9	3.75/3.00	1.25
D = Blocks	2, 18	.05/2.26	.02
B x C	3, 27	4.89/3.01	1.63
B x D	6, 54	1.48/2.05	.72
C x D	2, 18	1.55/2.37	.65
B x C x D	6, 54	2.23/1.28	1.74

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXVI

Summary of Analysis of Variance on the percentage of correct T2 responses in the One Side Key Positive (III) and Control (V) Conditions in Exp. III.

Source	df	MS/MSerror	F
B = Delay	3, 27	79.78/3.54	22.56 ***
C = Conditions	1, 9	.60/.91	.66
D = Blocks	2, 18	.09/1.36	.07
B x C	3, 27	1.77/3.43	.52
B x D	6, 54	1.29/1.79	.72
C x D	2, 18	2.04/2.69	.76
B x C x D	6, 54	2.27/2.04	1.11

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXVII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Intratrial (IV) and Control (V) Conditions in Exp. III.

Source	df	MS/MSerror	F
B = Delay	3, 27	84.78/3.72	22.76 ***
C = Conditions	1, 9	1.35/3.67	.37
D = Blocks	2, 18	1.95/3.01	.65
B x C	3, 27	3.52/3.10	1.13
B x D	6, 54	4.23/1.73	2.45 *
C x D	2, 18	.15/2.84	.05
B x C x D	6, 54	2.55/2.01	1.27

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXVIII

Two-tailed *t*-tests on retention loss scores, shorter delay percentage minus longer delay percentage, in Exp. III.

Conditions	Retention Interval	df	*t*	*p*
I vs. V	0 to 2 sec.	9	1.16	$p > .1$
II vs. V	0 to 2 sec.	9	2.06	$p > .05$
IV vs. V	0 to 2 sec.	9	1.75	$p > .1$
I vs. V	0 to 6 sec.	9	3.68	$p < .01$
III vs. V	0 to 6 sec.	9	1.98	$p > .05$
IV vs. V	0 to 6 sec.	9	1.52	$p > .1$

APPENDIX XXIX

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control, 1 Presentation, and 2 Presentations Conditions in Exp. IV.

Source	df	MS/MSerror	F
D = Delay	3, 27	68575.05/889.62	77.08 ***
C = Conditions	2, 18	7052.52/1010.37	6.98 **
I = ITI	2, 18	336.05/185.46	1.81
B = Blocks	3, 27	457.57/254.46	1.79
D x C	6, 54	500.72/290.46	1.72
D x I	6, 54	151.01/162.94	.93
D x B	9, 81	318.29/219.36	1.45
C x I	4, 36	144.97/242.86	.59
C x B	6, 54	244.36/177.97	1.37
I x B	6, 54	50.02/119.99	.42
D x C x I	12, 108	185.40/134.52	1.38
D x C x B	18, 162	136.62/170.38	.80
D x I x B	18, 162	281.84/172.25	1.64
C x I x B	12, 108	28.21/194.75	.14
D x C x I x B	36, 324	182.85/142.42	1.28

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXX

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control, 1 Presentation, and 2 Presentations Conditions (collapsed across ITIs and blocks) in Exp. IV.

Source	df	MS/MSerror	F
B = Conditions	2, 18	586.46/84.23	6.96 **
C = Delay	3, 27	5711.73/74.28	76.89 ***
B x C	6, 54	41.50/24.13	1.72

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXI

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 1 Presentation Conditions (collapsed across ITIs and blocks) in Exp. IV.

Source	df	MS/MSerror	F
B = Conditions	1, 9	346.74/72.51	4.78
C = Delay	3, 27	3261.01/70.69	46.13 ***
B x C	3, 27	15.75/22.41	.70

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 2 Presentations Conditions (collapsed across ITIs and blocks) in Exp. IV.

Source	df	MS/MSerror	F
B = Conditions	1, 9	1169.84/150.71	7.76 *
C = Delay	3, 27	3885.19/56.14	62.21 ***
B x C	3, 27	74.82/27.65	2.71

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXIII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control, 1 Presentation, and 2 Presentations Conditions at each delay in Exp. IV.

0-sec. Delay

Source	df	MS/MSerror	F
Conditions	2, 18	15.41/8.89	1.73

2-sec. Delay

Source	df	MS/MSerror	F
Conditions	2, 18	132.36/36.48	3.63 *

6-sec. Delay

Source	df	MS/MSerror	F
Conditions	2, 18	248.81/47.55	5.23 *

10-sec. Delay

Source	df	MS/MSerror	F
Conditions	2, 18	314.38/63.84	4.93 *

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXIV

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control Condition in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	43.12/3.97	10.87 ***
C = ITI	2, 18	.03/.55	.05
D = Blocks	1, 9	.15/.47	.32
B x C	6, 54	.78/.67	1.18
B x D	3, 27	.03/.69	.04
C x D	2, 18	.39/.32	1.20
B x C x D	6, 54	.82/.73	1.11

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXV

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 1 Presentation Conditions at the 2-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	54.18/3.15	17.22 ***
C = Conditions	1, 9	34.23/1.28	26.73 ***
D = Blocks	1, 9	2.03/.75	2.71
B x C	3, 27	3.61/1.15	3.15 *
B x D	3, 27	1.58/1.00	1.57
C x D	1, 9	1.60/.32	4.97
B x C x D	3, 27	.22/.98	.22

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXVI

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 1 Presentation Conditions at the 20-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	29.76/3.02	9.86 ***
C = Conditions	1, 9	.90/1.09	.82
D = Blocks	1, 9	2.03/.69	2.93
B x C	3, 27	.30/.51	.59
B x D	3, 27	.76/.70	1.08
C x D	1, 9	3.60/.91	3.98
B x C x D	3, 27	.80/.68	1.18

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXVII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 1 Presentation Conditions at the 40-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	30.71/2.41	12.73 ***
C = Conditions	1, 9	.23/.81	.28
D = Blocks	1, 9	2.03/.55	3.66
B x C	3, 27	.24/1.10	.22
B x D	3, 27	.28/.53	.52
C x D	1, 9	.03/.19	.13
B x C x D	3, 27	.28/.49	.55

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXVIII

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 2 Presentations Conditions at the 2-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	35.08/1.47	23.92 ***
C = Conditions	1, 9	21.76/3.02	7.20 *
D = Blocks	1, 9	1.06/.49	2.17
B x C	3, 27	2.02/1.49	1.36
B x D	3, 27	1.02/.73	1.39
C x D	1, 9	.76/.79	.95
B x C x D	3, 27	.86/1.39	.61

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XXXIX

Two-tailed *t*-tests on retention loss scores, shorter delay percentage minus longer delay percentage, in Exp. V.

Conditions	Retention Interval	df	*t*	*p*
Control vs. 2 Presentations (ITI = 2 sec.)	0 to 6 sec.	9	2.73	$p < .05$
Control vs. 2 Presentations (ITI = 20 sec.)	0 to 2 sec.	9	3.54	$p < .01$

APPENDIX XL

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 2 Presentations Conditions at the 20-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	28.52/2.21	12.92 ***
C = Conditions	1, 9	3.03/1.32	2.29
D = Blocks	1, 9	.23/1.04	.22
B x C	3, 27	.78/.68	1.14
B x D	3, 27	1.54/.97	1.59
C x D	1, 9	.90/.86	1.05
B x C x D	3, 27	.52/1.09	.48

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XLI

Summary of Analysis of Variance on the percentage of correct T2 responses in the Control and 2 Presentations Condition at the 40-sec. ITI in Exp. V.

Source	df	MS/MSerror	F
B = Delay	3, 27	30.96/2.52	12.28 ***
C = Conditions	1, 9	9.51/1.15	8.30 *
D = Blocks	1, 9	1.81/1.39	1.30
B x C	3, 27	.31/.89	.34
B x D	3, 27	.11/.63	.17
C x D	1, 9	.01/.70	.01
B x C x D	3, 27	.37/.83	.45

*** $p < .001$

** $p < .01$

* $p < .05$

APPENDIX XLII

A discussion of the possibility of the operation of a ceiling effect artifact in Experiments I through V.

The more rapid rate of forgetting in the Interference Condition than in the Control Condition has been attributed to the operation of PI. However, an alternate interpretation in terms of a ceiling effect on control performance is possible. It could be argued that control performance at the 0-sec. delay is so close to asymptote (i.e., 100%) that the 0-sec. delay performance is not an accurate reflection of the strength of the T2 memory. That is, it could be argued that the strength of the T2 memory is greater than that necessary to maintain asymptotic performance at the 0-sec. delay. Furthermore, since the 0-sec. delay performance in the Control Condition does not accurately reflect the strength of the T2 memory, the amount of interference obtained at the 0-sec. delay (as measured by subtracting the interference percentage from the control percentage) is also inaccurate. That is, the ceiling effect at the 0-sec. delay may result in a consistent underestimation of the true amount of interference at the 0-sec. delay. Thus, the increase in the amount of interference from the 0- to the 2-sec. delay may not be caused by the operation of PI, but rather may result from an underestimate of the amount of interference at the 0-sec. delay combined with an accurate estimate of the amount of interference at the 2-sec. delay. The 2-sec. delay data represent an accurate estimate of the amount of interference since control performance at this delay is well below asymptote (i.e., 100%). It should be pointed out that while the PI interpretation can account for increasing interference over the first 6 sec. of the retention interval, the ceiling effect interpretation can only account for increasing interference over the first 2 sec. of the retention interval.

It certainly is of considerable importance to determine whether the increase in the magnitude of the interference effect, from the 0- to the 2-sec. delay, in the present experiments was a true PI effect or an artifact of the ceiling effect. To accomplish this task, the ten Ss were divided into two groups of five Ss each. Group CE (ceiling effect) consisted of the five birds with the highest percentage of correct responses in the Control Condition at the 0-sec. delay, while Group NoCE (no ceiling effect) consisted of the five birds with the lowest percentage of correct responses in the Control Condition at the 0-sec. delay. In Exp. I, this division resulted in Group CE having a mean of 99.2% correct at the 0-sec. delay in the Control Condition, while Group NoCE had a mean of only 90.0% correct at the 0-sec. delay in the Control Condition. Thus, the birds in Group CE are clearly at asymptote and a ceiling effect could be operative, while the birds in Group NoCE are clearly not at asymptote and a ceiling effect could not operate. A ceiling effect interpretation would predict an increase in the amount of interference from the 0- to the 2-sec. delay in Group CE but not in Group NoCE. On the other hand, a PI interpretation would not predict a differential increase in the amount of interference as a function of performance at 0-sec.

The results of the ceiling effect-no ceiling effect analyses are shown in Table A. Of the four comparisons made between Group CE and NoCE in Exp. I, three demonstrated a greater increase in the amount of interference from the 0- to the 2-sec. delay in Group NoCE than in Group CE. This finding clearly contradicts the ceiling effect interpretation. In only one case, the 4 T1 Presentations Condition, did Group CE demonstrate a greater increase in interference than Group NoCE. Nevertheless, Group NoCE still demonstrated increasing interference over the first 2 sec. of the retention interval and this increase cannot be interpreted in terms of a ceiling effect artifact.

In Exp. II, the CE-NoCE division resulted in Group CE having a mean of 97.2% correct and Group NoCE having a mean of 88.9% correct at the 0-sec. delay in the Control Condition. In the Sample Present Condition (Fig. 9), Group CE showed a greater increase in the amount of interference from 0 to 2 sec. than did Group NoCE. However, the substantial increase in the amount of interference demonstrated by Group NoCE (11.2 percentage points) cannot be interpreted in terms of a ceiling effect artifact. In subcondition B (Fig. 10), no argument for a ceiling effect can be maintained since six of the ten Ss had a higher percentage of correct responses at the 0-sec. delay in the Interference Condition (subcondition B) than in the Control Condition. When the birds were divided into CE and NoCE Groups, it was found that Group CE had a higher percentage of correct responses at the 0-sec. delay

Table A

Some data relevant to the ceiling effect artifact versus the PI interpretation of the increase in interference from the 0- to the 2-sec. delay in Exp. I, II, and IV.

Exp.	Condition	Group	Amount of Interference 0 sec.	2 sec.	Increase 0 to 2 sec.
I	Interference (Fig. 5)	CE (99.2%)	12.2	17.8	5.6
		NoCE (90.0%)	8.1	16.4	8.3
I	1 T1 Presentation (Fig. 6)	CE (99.2%)	6.7	10.9	4.2
		NoCE (90.0%)	0	12.5	12.5
I	4 T1 Presentations (Fig. 6)	CE (99.2%)	12.5	26.7	14.2
		NoCE (90.0%)	14.2	20.9	6.7
I	6 T1 Presentations (Fig. 6)	CE (99.2%)	17.5	15.9	- 1.6
		NoCE (90.0%)	10.0	15.9	5.9
II	Sample Present (Fig. 9)	CE (97.2%)	1.1	18.3	17.2
		NoCE (88.9%)	4.4	15.6	11.2
IV	1 T1 Presentation (Fig. 13)	CE (99.0%)	1.7	6.9	5.2
		NoCE (90.6%)	1.9	2.3	.4
IV	2 T1 Presentations (Fig, 13)	CE (99.0%)	2.3	10.4	8.1
		NoCE (90.6%)	2.5	3.8	1.3

All data is in percentage points.

The percentages in parentheses after the group designation represent the mean of that group at the 0-sec. delay in the Control Condition.

Amount of interference: percentage of correct T2 responses in the Control Condition minus percentage of correct T2 responses in the Interference Condition.

Increase in interference from 0 to 2 sec.: Amount of interference at the 2-sec. delay minus amount of interference at the 0-sec. delay.

in subcondition B (98.3%) than in the Control Condition (97.2%). Thus, no ceiling effect could operate in Group CE. In addition, of course, no ceiling effect could operate in Group NoCE since control performance at the 0-sec. delay was only at the 88.9% correct level, far below asymptote.

As was the case for subcondition B in Exp. II, no ceiling effect could be operating on any of the four Interference Conditions in Exp. III (Fig. 11). This was the case since interference performance was above control performance at the 0-sec. delay in all four Interference Conditions. Thus, the argument that the interference generated at the 0-sec. delay was masked by asymptotic control performance at that delay (i.e., the ceiling effect argument) cannot be maintained when interference performance exceeds control performance at the 0-sec. delay.

CE and NoCE Groups were formed in Exp. IV. Group CE had a mean of 99.0% correct and Group NoCE a mean of 90.6% correct at the 0-sec. delay in the Control Condition. The increase in the magnitude of the interference effect from the 0- to the 2-sec. delay was analyzed as a function of these groups for both the 1 T1 Presentation Condition and the 2 T1 Presentations Condition (Fig. 13). In both Interference Conditions, Group CE showed a much greater increase in the amount of interference from the 0- to the 2-sec. delay than did Group NoCE. In addition, the increase shown by Group NoCE was negligible. Here then is the first instance in which a ceiling effect artifact may have, in large part, produced the weak increasing interference effect obtained in Exp. IV.

It should be pointed out that the CE-NoCE analysis does not indicate that a ceiling effect artifact was responsible for the increasing interference. Rather, the analysis only indicates that the possibility of a ceiling effect artifact cannot be ruled out in Exp. IV.

Unfortunately, legitimate ceiling effect and no ceiling effect groups could not be formed in Exp. V. Control performance at the 0-sec. delay was so high that Group CE had a mean of 100% correct and Group NoCE had a mean of 94.2% correct. On the basis of the high performance in Group NoCE, it could be argued that this group was also subject to the possible operation of a ceiling effect artifact. However, on the basis of the results of the CE-NoCE analyses of prior experiments, it seems unlikely that the large increase in the amount of interference from the 0- to the 2-sec. delay at the 2-sec. ITI in Exp. V (Table 6) could be entirely produced by the operation of a ceiling artifact.

On the basis of the CE-NoCE analyses, it can be concluded that the increase in the amount of interference from the 0- to the 2-sec. delay in the first three experiments was not produced by a ceiling effect artifact. Rather, the increase in the amount of interference seems clearly to have been produced by the operation of PI. In fact, in most cases in the first three experiments, birds which could not have been affected by a ceiling effect artifact showed a larger increase in interference than birds which could have been affected by a ceiling effect artifact. Exp. IV is the only experiment which yielded evidence compatible with the notion that a ceiling effect artifact may have resulted in the weak increasing interference effect which was obtained in that experiment.

Before leaving this topic, one additional aspect of the data presented in Table A deserves consideration. Recall that the ceiling effect argument predicts that Group CE should result in a greater increase in interference because of an underestimation of interference at the 0-sec. delay and an accurate estimation of interference at the 2-sec. delay. Thus, Group CE should result in considerably less interference than Group NoCE at the 0-sec. delay, while both groups should result in an equal amount of interference at the 2-sec. delay. An examination of the four cases in which Group CE showed a greater increase in interference than Group NoCE reveals that in all cases the fact that Group CE showed more interference than Group NoCE at the 2-sec. delay was mainly responsible for the differential increase in interference. This point is illustrated more clearly in Table B. In each of the four cases, the greater increase in interference demonstrated by Group CE is composed of two components. The first component is produced by the fact that Group CE showed less interference at the 0-sec. delay than Group NoCE; this component is the true ceiling effect component. The second component is produced by the fact that Group CE showed more interference at the 2-sec. delay than Group NoCE; this component cannot be attributed to a ceiling effect. In three of the four cases, the non-ceiling effect component

Table B

The greater increase in interference from the 0- to the 2-sec. delay for Group CE than for Group NoCE is shown as the sum of two components.

Exp.	Condition	NoCE minus CE (0-sec. delay) (ceiling effect component)	CE minus NoCE (2-sec. delay) (nonceiling effect component)	CE minus NoCE (interference increase from 0 to 2 sec.)
I	4 T1 Presentations	1.7	5.8	7.5
II	Sample Present	3.3	2.7	6.0
IV	1 T1 Presentation	.2	4.6	4.8
IV	2 T1 Presentations	.2	6.6	6.8

All data is in percentage points.

Ceiling effect component (0-sec. delay): Amount of interference demonstrated by Group NoCE minus amount of interference demonstrated by Group CE at the 0-sec. delay.

Nonceiling effect component (2-sec. delay): Amount of interference demonstrated by Group CE minus amount of interference demonstrated by Group NoCE at the 2-sec. delay.

Third column: Group CE increase in interference from 0 to 2 sec. minus Group NoCE increase in interference from 0 to 2 sec. Or, sum of ceiling effect and nonceiling effect components.

contributed more to the greater Group CE increase in interference than did the ceiling effect component. In addition, in at least two cases, the contribution of the ceiling effect component can certainly be considered to be negligible.

On the basis of the preceding discussion and the data presented in Tables A and B, it can be concluded that the results of the present experiment are totally uncontaminated by a ceiling effect artifact. All cases in which increasing interference with increasing delay was obtained can be considered to reflect the operation of a true PI effect.