

INFORMATION TO USERS

This was produced from a copy of a document sent to us for microfilming. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help you understand markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure you of complete continuity.
2. When an image on the film is obliterated with a round black mark it is an indication that the film inspector noticed either blurred copy because of movement during exposure, or duplicate copy. Unless we meant to delete copyrighted materials that should not have been filmed, you will find a good image of the page in the adjacent frame. If copyrighted materials were deleted you will find a target note listing the pages in the adjacent frame.
3. When a map, drawing or chart, etc., is part of the material being photographed the photographer has followed a definite method in "sectioning" the material. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.
4. For any illustrations that cannot be reproduced satisfactorily by xerography, photographic prints can be purchased at additional cost and tipped into your xerographic copy. Requests can be made to our Dissertations Customer Services Department.
5. Some pages in any document may have indistinct print. In all cases we have filmed the best available copy.

University
Microfilms
International

300 N. ZEEB RD., ANN ARBOR, MI 48106

8217478

Su, Tuan-Tuan

EFFECT OF PARTIALLY COVERING STRING ARRAYS ON PATTERNED
STRING PERFORMANCE OF PLATYRRHINE MONKEYS

The University of Arizona

PH.D. 1982

University
Microfilms
International 300 N. Zeeb Road, Ann Arbor, MI 48106

EFFECT OF PARTIALLY COVERING STRING ARRAYS ON PATTERNED
STRING PERFORMANCE OF PLATYRRHINE MONKEYS

by

Tuan-Tuan Su

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 2

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read
the dissertation prepared by Tuan-Tuan Su
entitled Effect of Partially Covering String Arrays on Patterned
String Performance of Platyrrhine Monkeys

and recommend that it be accepted as fulfilling the dissertation requirement
for the Degree of Doctor of Philosophy.

James E. King 3/7/82
Date

Robert B. Bechtel 3/9/82
Date

Muller H. Hutter 3/7/82
Date

Neil R. S. 3/9/82
Date

Richard H. H. 3/9/82
Date

D. M. Hunter

Final approval and acceptance of this dissertation is contingent upon the
candidate's submission of the final copy of the dissertation to the Graduate
College.

I hereby certify that I have read this dissertation prepared under my
direction and recommend that it be accepted as fulfilling the dissertation
requirement.

James E. King 3/7/82
Dissertation Director Date

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Juan-Juan Su

ACKNOWLEDGMENTS

I would like to express my appreciation for the guidance of the members of my committee: Dr. Neil R. Bartlett, Dr. Robert B. Bechtel, Dr. Sigmund Hsiao, Dr. William H. Ittelson, and Dr. James E. King. I especially appreciate the support and advice of my major professor, Dr. James E. King, during the trying times of this study.

I would like to thank Mr. Skip McGrogan and Mr. Jim Lentz for friendship and technical aid. I would also like to thank my husband, Chang-Kwang Wang, for constant emotional support and encouragement throughout this study.

The life-long support of my parents, Mr. and Mrs. Yang-Chou Su, in my academic journey can never be repaid or sufficiently acknowledged.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	vi
LIST OF TABLES	viii
ABSTRACT	ix
1. INTRODUCTION	1
The History of Patterned String Problems	2
The History of the Delayed-Response	10
The Sequential State Theory (SST)	21
2. PURPOSE	29
3. EXPERIMENT I	31
Method	31
Subjects	31
Apparatus	32
Adaptation	33
Testing Procedure	33
Hypothesis Analyses	34
Results	36
Discussion	37
4. EXPERIMENT II	43
Method	43
Subjects	43
Apparatus	44
Adaptation	44
Testing Procedure	44
Results	44
Discussion	49
5. EXPERIMENT III	52
Method	53
Subjects	53
Apparatus	53

TABLE OF CONTENTS--Continued

	Page
Adaptation	53
Testing Procedure	53
Results	55
Discussion	62
6. GENERAL DISCUSSION	67
LIST OF REFERENCES	71

LIST OF ILLUSTRATIONS

Figure	Page
1. Triphasic Model of Acquisition of Complex Learning	27
2. $P(D)$ as a Function of Type of Cover Placement and Delay Interval on Parallel String Patterns	38
3. $P(+)$ as a Function of Type of Cover Placement and Delay Interval on Parallel String Patterns	39
4. Mean Probability of Values, D , B , P/Q , R , and A by Trials	40
5. $P(B)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns	46
6. $P(P)/P(Q)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns	47
7. $P(F)/P(G)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns	48
8. $P(F)/P(G)$ as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns	57
9. $P(R)$ as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns	58
10. K as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns	59
11. $P(+)$ as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns	61

LIST OF ILLUSTRATIONS--Continued

Figure	Page
12. Probability of Values D, A, and + as a Function of Conditions 1-10 and Condition 11 (Control Condition) on Crossed String Patterns	63

LIST OF TABLES

Table	Page
1. Levine's Hypothesis	24
2. Possible States of Sequential State Theory (SST)	26

ABSTRACT

This study involved a new type of patterned string task in which a delay period was imposed between string presentation and opportunity to respond.

In Experiments I and II, six squirrel monkeys were tested on parallel and crossed string problems in a Wisconsin General Test Apparatus. After the parallel or crossed string pattern was viewed by the subject for five seconds, one of three conditions was carried out: (a) a cover was placed over the ends of the strings thereby obscuring the food cup at the end of one string (far cover); (b) a cover was placed over the center portion of the strings allowing the subject to view the food cup but breaking the visual continuity of the strings (middle cover); (c) a cover was placed behind the string pattern thereby not obstructing the subject's view (no cover). After placing the cover according to one of three conditions, a Plexiglas screen was raised either immediately or after a five-second delay thus allowing the subject to respond. Results indicated that squirrel monkeys committed more errors under the far cover condition than under the no cover condition on parallel string patterns. On the crossed string pattern, squirrel monkeys manifested more position preference during the middle cover condition than during the no cover condition or during the far cover condition.

In Experiment III, six capuchin monkeys were tested under 11 conditions on crossed string patterns. Eleven conditions were used to vary the lighting and the location of covering during the 12-second delay. Conditions 1 through 10 were conducted either in light or in dark when a cover was imposed during the beginning, middle, or end four seconds or during the beginning or end eight seconds. Condition 11 was no cover with continuous lighting for 12 seconds. Regardless of light or dark conditions, capuchin monkeys manifested most correct responses when the full pattern was visible during the last four or the last eight seconds before the response. The result suggests that information received in the early part of the delay interval was used less efficiently than did that in the last part of the delay interval.

CHAPTER 1

INTRODUCTION

A patterned string problem is one of a variety of tasks used to test the perceptual abilities of animals (e.g., Harlow and Settlage, 1934; Finch, 1941; Riesen et al., 1953; Fischer and Kitchener, 1965). Typically, a food cup attached to one end of a string is baited with a reward and obscured from the view of the subject by an opaque screen. Then, the screen is raised and the subject is allowed to respond.

The technique used in this investigation was a combination of patterned string problems and delayed response. The new technique used a delay variable in a complex perceptual problem to test not only the perceptual performance of the subjects but the subject's use of its short-term memory as well. Thus, this task measured combined learning and cognitive capacities of New World monkeys. This was accomplished by having the subject first view a series of patterned string problems through a transparent screen for a constant time-interval and subsequently a cover was placed over the strings in one of three positions (see details in the Method section). After placing the cover, the transparent screen was raised which allowed the subject to respond either immediately or after a predetermined time of delay.

The response sequence of subjects in a variety of learning paradigms has been shown by the percentage of correct responses. In order to get more information concerning the systematic as well as random response tendencies in monkeys, Sequential State Theory (SST) offered an excellent means to measure these response tendencies. Thus, the results in this study were analyzed with the SST method and further evaluated the applicability of the SST method to different learning tasks.

The History of Patterned String Problems

Patterned string problems consist of presenting the subject with various configurations of two or more strings laid out on the stimulus presentation tray in a Wisconsin General Test Apparatus (WGTA). One of the strings has a conspicuous reward attached at one end while the other strings have no reward attached. The subject's task, then, is to obtain the reward by pulling in the one string with an attached reward. Task difficulty can be varied by changing the pattern or configuration of the strings on the tray.

Hobhouse (1901) was the first psychologist to use strings attached to food as a test of the ability of animals to solve problems. He studied these problems in informal experiments using a wide variety of animals including cats, dogs, monkeys, chimpanzees, and elephants. His research was, more often than not, informal and anecdotal and did not conclusively demonstrate discrimination of different strings problems by the cats and

dogs. Other early studies with patterned string problems were thoroughly reviewed by Richardson (1932).

The first systematic study on patterned string problems was conducted by Harlow and Settlage (1934). They devised two series of patterned string problems which ranged in difficulty from problems that were almost always solved to problems that were rarely solved. They also introduced training procedures which were easily replicated. They presented patterns in the same fixed order to each subject and used a constant number of trials per problem, a one-trial correction procedure, and a sufficient number of subjects to permit statistical comparisons. Thirty-one primates were used in this study including Catarrhine and Platyrrhine monkeys. All subjects showed a general "monkey level" of capacity in solving patterned strings problems, a level which was quantitatively and qualitatively superior to any non-primate form. No significant differences among the various genera of the Catarrhine or Platyrrhine monkeys was demonstrated. Simple patterned strings problems were solved almost immediately by all monkeys, those of intermediate difficulty were solved with some trouble, and more complicated problems were insolvable to all subjects.

Finch (1941) used eight chimpanzees to solve 11 patterned string problems. In order to obtain data directly comparable with the study of Harlow and Settlage, Finch duplicated as nearly as possible the Harlow and Settlage experimental design. The 10 problems in series II of Harlow and Settlage and a

new problem (strings converging to a point of contact and diverging) were used. Seven of eight chimpanzees solved all of 11 patterned string problems presented, including the two problems on which all of Harlow and Settlage's monkey subjects failed. In addition, only one chimpanzee immediately solved both the crossing and converging-diverging string problems. Six of the other seven subjects were able to compensate for the illusory effects and for the carried-over habit-interference in solving the converging-diverging problem. However, the ability to compensate for the illusory pattern of converging-diverging problem seemed to be lacking in monkeys.

Patterned string problems used in previous studies varied from one investigation to another until Finch (1941) duplicated the patterns of Harlow and Settlage (1934), in order to compare the capacities of chimpanzees and monkeys. Riesen et al. (1953) tried to extend this comparison to another of the anthropoid apes, the gorilla, and retained the essential features of the procedure described by Finch. They found that three young gorillas did almost as well as the adult chimpanzees tested by Finch. In other words, the young gorillas showed a range of performances comparable to that of chimpanzees and exceeding that of any species of monkey studied. They suggested that age as well as phylogenetic level are correlated with performance on these problems. The problems appear to constitute a series of complex visual perceptual tasks rather than tests of sensory acuity.

Although gradual improvement was shown in several studies of patterned string problems, the learning curves did not appear in the literature. Learning occurred in an unpublished study conducted by Davis in Harlow's laboratory during 1947 (see the 1948 reference of Harlow and Settlage to this study in the context of frontal lobe brain damage in monkeys), but difference in pattern difficulty could not be determined because all animals received patterns in a fixed order of difficulty. In order to determine the order of pattern difficulty, Davis and McDowell (1953) used a randomized order of pattern presentation. Six different patterns were presented in 16 stump-tail monkeys, one trial per pattern per day, in a random order. Each subject was adapted until it successfully obtained five pieces of food from a single baited string. They were then given each one of six patterns (box, crossing, pseudo-cross, double cross, angle cross and four-crossing patterns) daily for 75 days. Learning of patterned string problems was possible when the patterns were intermixed. The data also showed that the crossing strings pattern was significantly easier than any of the other patterns.

Patterned string problems can be regarded as a test of perceptual-learning ability and a particularly advantageous type of problem because comparative data are available on monkeys (Harlow and Settlage, 1934), chimpanzees (Finch, 1941), and young gorillas (Riesen et al., 1953). Therefore, Fischer and Kitchener (1965) attempted to provide comparative data on learning ability in Ponginae. Subjects were a pair of preadolescent orangutans,

three young gorillas and two infant orangutans. All subjects were tested with Finch's 11 strings problems. Like the gorillas, the orangutans had difficulty with the complex crossed and the pseudo-crossed problems; but all except the youngest orangutan mastered them and had no difficulty with any other problem. However, the efficiency of the other infant orangutan is striking. The data, considered with those for the youngest gorilla, showed that for Ponginae learning of patterned string problems occurred within the first year of life. This result appears consistent with the study for discrimination learning in neonate monkeys (Harlow, 1959) and pattern vision in very young human infants (Fantz, Ordy, and Udelf, 1962). Thus the data from the above studies (Harlow and Settlage, 1934; Finch, 1941; Fischer and Kitchener, 1965) imply that patterned string problems do not differentiate Ponginae. The more difficult problems (i.e., the complex crossed and the pseudo-crossed), however, may differentiate Ponginae from monkeys.

Patterned string problems were used in several studies on the effects of brain damage. Settlage (1939, p. 130) gave patterned string problems to monkeys before and after partial occipital lobe lesions. The performance of each of his animals declined immediately after surgery but subsequently recovered. He felt that the initial deficiency was due to a persistence of preoperative habits of bodily orientation and visual fixation and the existence of a gap in the operated subjects' visual world. The recovery was regarded as running parallel with a

closing gap in the visual world. This gap, which closed whether monkeys were trained or not, involved two processes: (a) learning to use perceived objects as inferring the existence of a larger situation and (b) development of capacity to respond on the basis of less than normal cues.

Harlow (1939) repeated many of the essential features of Settlage's (1939) study but placed animals in the dark for 10 days after they had learned string problems and again after subsequent occipital lobectomies. The first procedure did not interfere with their ability to solve patterned string problems, but impairment in solving patterned string problems followed unilateral occipital lobectomy and 10 days in darkness.

Harlow and Settlage (1948) reported that monkeys with frontal lobe lesions were inferior in performance to normal controls on string problems and were similar to animals with partial hemidecortication. Since subjects with frontal lobe lesions perform poorly in spite of intact vision, their deficit cannot be due to partial blindness. Further, since animals with gross unilateral lesions did far worse than animals that had merely undergone unilateral occipital lobectomies, it is likely that lesions of the association cortex interfere with habits of eye movements needed to see with a missing visual field. This also recalls deficits reported by Luria (1964), in frontal lobe lesioned human patients given instructions that demanded the extraction of information by scanning pictures systematically.

The aforementioned studies with adult rhesus monkeys (Harlow and Settlage, 1934), chimpanzees (Finch, 1941), gorillas (Riesen et al., 1953), and orangutans (Fischer and Kitchener, 1965) indicated that these primates are able to solve simple patterned string problems either immediately or after a brief period of learning. However, some studies with immature rhesus monkeys (Mason and Harlow, 1951), raccoons (Michels, Pustek, and Johnson, 1961), rock squirrels (King and Witt, 1966), and squirrel monkeys (Cha and King, 1969) showed that for these animals, solution of even a simple parallel pattern was not immediate and may require an extended period of learning.

Mason, Blazek, and Harlow (1956) showed that young macaques, in contrast to adult macaques, had great initial difficulty in solving the simple parallel-string pattern but demonstrated extensive learning when they had opportunity to practice. Therefore, a study by Michels et al. (1961) was designed to present three raccoons with an opportunity to learn the solution of Harlow-Settlage patterned string problems. The techniques were similar to those used with primates. It was found that raccoons could solve these problems. An unexpected result was that raccoons, after learning crossed and pseudo-crossed patterns separately, were able to perform efficiently on an intermixed series. The reason to account for this unexpected result was attention to tracing the chains visually. It appears, then, that a visual tracing of the string between source and reward was the important factor in problem solution, rather than

learning the pattern and the position of the food cup. Furthermore, what was tested, in this as in many comparative psychological problems, may well have been the efficacy of a training program rather than the ability of a species. The proficiency of the raccoons' performance, compared with those of primates, may be due to greater practice rather than inherent capacities.

Harlow and Settlage (1934) found highly efficient performance on string problems in adult macaques. In contrast, Mason et al. (1956) found that young macaques initially performed below chance on a simple crossed-string pattern. Thus, a study conducted by Mason and Harlow (1961) was designed to investigate changes in patterned string performance in rhesus monkeys from infancy to maturity while controlling experience. There were five groups of infants, an adolescent group, and a mature, adult group. Individuals in infant groups reached 60, 90, 120, 150, or 360 days of age before testing. The results clearly indicated efficiency in the solution of patterned string problems generally improved progressively with increasing age. All younger groups consistently preferred the incorrect string during the early phases of testing. The young monkeys often reached directly toward the food incentive and, hence, selected the string originating nearest the food. This result suggests that one of the principal differences in the patterned string performance of young, as compared with adolescent or mature, monkeys is the tendency of the older animals to make more effective use of the

information provided by the direction or patterning of the strings.

The raccoons tested by Michels et al. (1961) learned an intermixed series of crosses and pseudo-crosses following separate learning of the constituent patterns. However, the squirrel monkeys tested by Cha and King (1969) had considerable difficulty in learning an intermixed series of crosses and pseudo-crosses after these problems had been learned separately. The discrepancy in the result of Michels et al. and that of the Cha and King may be attributed to different amounts of practice. This result was again consistent with the supposition that the squirrel monkeys learn simple patterned string problems, not by tracing the path of the baited string to the food cup, but by forming a discrimination based upon the position of the food cup relative to the strings.

The History of the Delayed-Response

The delayed-response problem was introduced by Walter S. Hunter in 1913. It is the one behavioral test sensitive to a wide range of experimental manipulations and still is a favorite laboratory tool of comparative psychologists. The experimental paradigms for the delayed-response include direct delayed-response, indirect delayed-response, delayed alternation, and delayed matching to sample. It is assumed that performance derived from these paradigms reflects the operation of a short-term

memory system (Rosvold and Delgado, 1956; Stamm, 1961; Fletcher, 1965; Jarrard and Moise, 1971).

The direct delayed-response problem is probably the most widely used memory paradigm. The problem typically proceeds as follows: (1) The animals are allowed to view the two empty foodwells of a test tray that is out of reach. Behind the foodwells are identical objects. (2) The experimenter tries to attract the animal's attention and then places the reward in one of the two exposed foodwells and covers both foodwells with the objects. (3) After some predetermined delay interval, the tray is pushed forward within the animal's reach, and the subject is allowed to respond. If the subject responds to the previously baited foodwell, it receives a reward.

This paradigm has some disadvantages because it is unclear whether the salient baiting cue is the sight of food (eliciting consummatory responses), viewing the movements involved in baiting a foodwell, or some combination of both. Also, the time of stimulus presentation and delay interval cannot be precisely controlled. Therefore, the direct delayed-response paradigm appears to be unsuited for asking detailed questions about memory.

In the indirect delayed-response paradigm, a nonfood cue signals the correct location of the reward. For instance, the cue may be a light that briefly turns on behind one of the reward locations. The animals typically are given preliminary training in which they learn the significance of this cue

(i.e., they should respond to where the light was). The light cue substitutes for the direct observation of the reward in the direct delayed-response paradigm. The indirect paradigm has considerable advantage over the direct paradigm in that the stimulus duration and illumination can be kept constant from trial to trial, and the delay interval may be more precisely assigned. Thus, the indirect delayed-response method is considered to be a significant procedural advance for the study of what information is available during the cuing phase of delayed-response problem.

Delayed alternation has been used as a measure of short-term memory. In the spatial delayed-alternation problem, the reward alternates in position on each trial such that if reward was present on the previous trial in one position, it will be available in the opposite position for the current trial. To perform effectively, the animal must remember its preceding response and its outcome, then use a win-shift/lose-stay strategy to generate its current response. Since both a learning and a memory component are involved, some range of delay (intertrial) intervals seems necessary for analyzing the memory component. It seems that memory is important in this task since Jacobsen and Nissen (1937) found that performance decreased with increasing delays. However, the animals could conceivably avoid any memory problems by shifting their location after each correct response, maintaining their location until the next trial, and then responding to the nearest location. Stamm, Stepien, and Levine (1971)

reported this use of positional cues in the delayed alternation of prefrontally ablated monkeys.

The delayed matching-to-sample (DMTS) task has recently been used extensively in non-human primate memory research. In this paradigm a sample stimulus is presented and then, after some delay interval, two or more comparison stimuli are presented. Response to the stimulus identical to (i.e., matching) the sample is rewarded. The wide use of the DMTS task to study animal memory is partially due to the noted similarities in task requirements between it and the short-term memory paradigm used with humans (Devine et al., 1977). Also, the effects of amount of interpolated activity, repetition of the stimulus, and stimulus difficulty in the DMTS task are generally similar to the effects of these variables on human STM (Jarrad and Moise, 1971).

Various hypotheses have been advanced to explain the performance of the monkey with lesions in the frontal lobes on the delayed-response problem. Jacobsen's (1936) hypothesis of loss of immediate memory, Malmö's (1942) of increased susceptibility to retroactive inhibition, and Richter and Hines's (1938) of heightened distractibility emphasized the importance of the events occurring during the period of delay. Finan (1942) and Riopelle and Churukian (1958), by way of contrast, emphasized decrement in learning on the pre-delay of delayed response.

Reduction of visual stimulation during the delay has been one of the important variables affecting delayed-response

performance. It has been accomplished in past experiments either by interposing an opaque barrier between the subject and the response loci (Meyer and Harlow, 1952) or by turning off all illumination in the testing area (Malmo, 1942; McDowell and Brown, 1960). Both of these operations have two possible but opposing consequences upon delayed-response performance. First, as emphasized by Malmo, darkness eliminates extraneous visual stimulation and therefore increases the likelihood that pre-delay association to the rewarded locus will be retained. Second, darkness prevents the subject from maintaining visual orientation to the rewarded locus and would thus be expected to lower the strength of the pre-delay association.

Lowering the opaque screen during the delay interval of a delayed-response problem increased errors by 50% in normal experimentally sophisticated monkeys (Meyer and Harlow, 1952; Riopelle, 1969). Battig, Rosvold, and Mishkin (1960) noted that frontal animals could not succeed at one-second delays when the screen was used whereas without the screen they could solve five-second delayed-response problems. Fletcher and Davis (1965) reported that when the screen was lowered within one second of the beginning of the delay and remained down for the longest duration (seven seconds), the resulting deficit in performance was greatest. They concluded that "one may make the delayed-response problem more or less difficult simply by lowering the screen at various times for various durations" (Fletcher and Davis, 1965, p. 741). However, Motiff, DeKock, and Davis (1969) found that

the lowering of the opaque screen caused a significant decrement in performance whereas the concealing of the objects by a small hand screen did not reduce performance significantly. This result indicated that, to the subject, lowering the screen meant the end of a trial. With the end of a trial, the usually good strategy of forgetting the previous trial and preparing for the next seems to have been followed here, but with detrimental effects.

The degree of ambient illumination prevailing in the delay interval frequently has a profound effect upon delayed-response performance. Malmo (1942) reported that rhesus monkeys showed progressively worse performance in an indirect delayed-response problem as the degree of chamber illumination during the delay was increased. McDowell and Brown (1960) demonstrated that rhesus monkeys tested on a nonspatial delayed-response task improved their performance significantly more under conditions of darkness during the delay interval than did those under conditions of regular room illumination. With a spatial task, however, performance was reversed and subjects performed significantly better under the light delay conditions. A similar result involving superior performance under light conditions with a spatial delayed-response task was reported on squirrel monkeys (King and Clawson, 1966).

In a comparative effort, King, Flamingam, and Rees (1968) studied squirrel monkeys under conditions comparable to the King and Clawson (1966) experiment. In addition to the

spatial task, a nonspatial one was also introduced. Unlike McDowell and Brown, however, King et al. (1968) did not find a difference under light and dark conditions as a function of task type. Performance was better under light conditions for both types of tasks.

The findings of previous primate studies on the effect of interpolated illumination with spatial and nonspatial delayed-response problems seem inconsistent, in that light has had both inhibitory and facilitatory effects on performance. However, with the delayed matching-to-sample task using capuchin monkeys performance was superior when the delay interval was spent in darkness rather than in moderate illumination (D'Amato and O'Neill, 1971; Etkin, 1972). The same inhibitory influence of illumination with DMTS task has been observed in pigeons (Grant and Roberts, 1976; Maki, Moe, and Bierley, 1977; Roberts and Grant, 1978; Maki, 1979). Corresponding results have also been obtained with dolphins using an auditory DMTS task. Herman (1975) reported that dolphins made more errors when irrelevant auditory stimulation (e.g., noise) was present during the delay interval than when it was absent.

The degree of exposure to light was varied by using different durations of delay and filling the delay with houselight. Another way to manipulate the degree of exposure to illumination is to keep duration of delay constant and to vary the length of time within the delay for which the houselight is illuminated. In other words, this procedure is to examine the effect of point

of interpolated illumination. Etkin (1972, Experiment 2) used capuchin monkeys in DMTS task. The illumination probes of varying duration was inserted at either the beginning or the end of a delay interval. For instance, in a dark 18-second delay interval, a one-second light probe (housetlight-on) was presented either during the first two or the last two seconds of the retention interval. He found that although performance decreased with duration of the light probe, placement of the probe at the beginning or end of the delay had no significant effect on matching accuracy. A close examination of the Etkin (1972) study suggests that point of interpolation may in fact have an effect upon degree of matching accuracy. His subjects were less accurate with end probe placements than with beginning placements at probe durations of one, two, four, and eight seconds. Only at the largest probe, 16 seconds, did the end condition exceed the beginning condition. It seems possible that his subjects performed slightly better when the light probe occurred at the beginning of the delay interval than at the end but that the use of only three monkeys did not provide a sensitive test to produce a significant effect of point of interpolation (see Roberts and Grant, 1978, p. 222). Similar result involving failure to find an effect of point of interpolated light on DMTS performance has been reported with pigeons (Maki et al., 1977). But with a careful examination, it also showed a difference in the direction of higher accuracy with beginning placement than with end placement. In an experiment using a dolphin with auditory DMTS task,

Herman (1975) presented a 15-second delay and found no differential effect of point of interpolation.

Several hypotheses have been suggested concerning the nature of the lighting interference phenomenon. A hypothesis states that delay interval darkness allows more effective consolidation of the sample "memory trace" than does the illumination that is present during the houselight-on condition. Another related hypothesis states that reducing ambient illumination to a very low level immediately after sample presentation can preserve after-images that aid as cues for subsequent responses. According to these two hypotheses, it is predicted that the light probe inserted at the beginning of the delay interval should prove more deleterious than the light probe inserted at the end of the delay interval, if consolidation or preservation of after-image can be facilitated by delay-interval darkness. Etkin's (1972) study failed to find this predicted effect. Instead, it demonstrated that houselight presented at the end of a delay produced stronger interference than light presented at the beginning of a delay. Another study conducted by Roberts and Grant (1978) with pigeons indicated that houselight placed at the end of a 10-second delay interval led to more retroactive interference than placement of light at the beginning of the interval. These findings did not support the above two hypotheses. However, these findings confirmed Grant and Roberts' (1976) memory-loss hypothesis. The memory-loss hypothesis proposes that illuminated delays disrupt performance because introduction of new information for

processing lead to loss of memory of the sample stimulus as a result of its decay. Thus, the finding of beginning-end effect can be explained in terms of a temporary loss of accessibility of the memory trace during a light delay but partial recovery of accessibility occurred during a period of darkness.

Kendrick's (1980) study on indirect delayed response with capuchin monkeys was designed to measure the effect of the temporal sequencing of different lighting conditions on learning by varying the onset and offset of light and dark. He found that each lighting condition which had an initial period of darkness produced higher probabilities of correct responding than the comparable condition with an initial period of light. This result was consistent with the previous hypothesis that reducing ambient illumination at the beginning of the delay period with darkness improved performance.

Another hypothesis, competing with the memory-loss hypothesis, is the temporal discrimination hypothesis (D'Amato, 1973). Temporal discrimination hypothesis states that animals forget not because of decay of a memory trace but because of a failure to discriminate which of the choice stimuli has been seen most recently as a sample stimulus. The more distant in time the presentation of the sample took place, the more difficult is the temporal discrimination between the sample stimulus and the incorrect comparison stimulus. D'Amato's interpretation of the illumination effect has been integrated with his temporary discrimination hypothesis of forgetting effects. The inhibitory

effect of illumination occurred because an illuminated delay, filled with visual stimulation, gives animals the impression of a longer period of time than those a darkened delay. Thus, temporal discrimination is more difficult following an illuminated delay than following a darkened delay.

A number of recent papers suggest that none of the above hypotheses provides adequate explanations of the illumination effect. These papers also suggest that better performance following a dark delay than following an illuminated delay may be due to an artifact of the training procedures. Previous studies in primates and pigeons have not considered baseline illumination condition an important variable. In all cases, the training or baseline condition involved relatively dark delays and test conditions included illuminated delay. Tranberg and Rilling (1980) conducted an experiment with pigeons to determine whether a change in delay-interval illumination, either an increase or a decrease, disrupts DMTS performance. During training, four different baseline and test conditions were used: houselight on during both intertrial and delay intervals, houselight on during intertrial interval but off during delay interval, houselight off during both intertrial and delay interval, and houselight off during intertrial interval but on during delay interval. The test conditions involved a change, relative to the respective baseline, in delay-interval illumination. In other words, the subjects in a houselight-on condition during the delay were switched to a houselight-off condition. In all cases, whether

the delay-interval illumination changed from dark to light or light to dark, performance dropped relative to baseline levels. It suggests that illumination per se introduced during delay intervals does not disrupt performance. Rather, a change in delay-interval illumination relative to the baseline causes this disruption.

Cook (1980) used a reversed procedure of previous experiments and first trained pigeons to tolerate a delay with the houselight on. Then, in the test session the houselight was turned off during the delay interval. The findings showed that reduced illumination during the delay caused a disruption in DMTS performance, similar to Tranberg and Rilling's findings. The findings of both Cook and Tranberg and Rilling studies differ from those of a previous study that manipulated a similar variable (D'Amato and O'Neill, 1971).

In summary, it seems clear that the empirical findings of studies of houselight effect are inconsistent with each other and none of the hypotheses is able to adequately account for this effect. Therefore, variables found to influence the houselight effect need to be studied further to reveal the basis of this effect.

The Sequential State Theory (SST)

The performance on patterned string problems or delayed responses has traditionally been measured by percentage of correct responses. This traditional measure is not adequate

because it does not entirely reveal the components of learning. Actually, learning contains random and nonrandom components in addition to correct responses. The recent experiments (Kendrick, 1980; Lentz and King, 1981) on delayed response performance by nonhuman primates have increasingly strengthened the importance of measuring these random and nonrandom components.

The first systematic attempt to examine response tendencies and the type of errors these tendencies would produce was made by Krechevsky (1932) who analyzed the performance of rats that had learned multiple unit maze discriminations. Krechevsky was impressed by the frequency of three types of systematic responses (position, perseveration, and alternation habits) that often appeared in protocols of his rats prior to their attainment of the learning criterion. Furthermore, he saw these three types of errors as systematic attempts by his rats to solve the problem by attending to some stimulus dimension of the maze regardless of whether it was relevant or not. Therefore, Krechevsky used the term "hypotheses" to describe these presumed attempts at solution.

A later approach was made by Harlow (1950) who demonstrated the existence of similar systematic response tendencies by rhesus monkeys in the discrimination learning-set paradigm. Harlow found four different response patterns which he called "error factors." The four error factors were position habit (preponderance of response to one of the two sides), stimulus perseveration (relative excess of consecutive errors following

a first-trial error), differential cue (response to the position previously yielding food rather than to the object), and response shift (excessive response to the negative object following response to the positive object). A major weakness in Harlow's technique was that the measures were separately improvised for each error factor. As a result, the proportion of responses controlled by a given error factor could not be determined, nor could the strengths of the various error factors be compared.

To eliminate this weakness, Levine (1959, 1965) developed a theoretical framework for treating a large variety of systematic patterns of responses in the object discrimination learning set experiment. His model had several special features. Specifically, the foregoing difficulties were eliminated: all patterns were measured in a standard manner, yielding estimates of the proportion of responses which were manifestations of each tendency, and these proportions were additive. Levine once again used the terminology of Krechevsky and labeled the response patterns "hypotheses" since they could measure both error-producing and reward-producing patterns. He defined a set of nine hypotheses (see Table 1). An important hypothesis in the set was random responding which had not been included in the earlier technique described by Harlow (1950) and Krechevsky (1932). Levine's analysis was based on a categorization of trials one through three into 32 different types defined by sequences of stimulus presentation and responses within the three-trial sequences. The value of each hypothesis could then be expressed

Table 1. Levine's Hypotheses

Hypothesis	Definition	Manifestation*
Position preference	Responding to only one position	III
Position alternation	Alternating between positions from trial to trial	IOI
Stimulus preference	Responding to only one object	+++ , ---
Stimulus alternation	Alternating between objects from trial to trial	+--+ , --+
Win-stay lose-shift with respect to position	Repeating a rewarded response to a position or shifting a non-rewarded response to another position	I+I+I, I+I-O, I-O+O, I-O-I
Lose-stay win-shift with respect to position	Shifting a response to another position after reward or repeating a response to a nonrewarded position	I+O+I, I+O-O, I-I+O, I-I-I
Win-stay lose-shift with respect to the object	Repeating a rewarded response to an object or shifting from a non-rewarded object to a rewarded one	+++ , +--+
Third-trial learning	Correct response on third trial but not on the second	---+ , +--+
Residual category	Random responding	All possible manifestations

*+ indicates a correct response, - indicates an incorrect response, I indicates the first position responded to on a three-trial sequence, O indicates the other position.

as a proportion in that the sum of all the values of hypothesis must equal 1.00. A restriction of Levine's technique is that subjects retain the same hypothesis during all three trials of any three-trial sequence. There is no provision for a change of hypothesis within the sequence. This assumption is apparently justified for simple concept learning by adult humans (Levine, 1966, 1967; Levine, Miller and Steinmeyer, 1967) but, as Levine has acknowledged, it is not realistic for describing most animal learning.

Through a modification of Levine's technique, King and Fobes (1975) developed a technique which is applicable to animal learning and does not necessitate the assumption that biases and sequential dependencies are expressed in three-trial units. They used the term sequential state theory (SST) to describe the measurement model since each trial is conceptualized as resulting from one of several possible theoretical states which may reflect correct responding, a simple response bias, a sequential dependency from the previous trial, or a purely random responding. Table 2 shows the constituent states measured by SST, their definitions and their manifestations in response sequences. SST postulates three phases for acquisition of complex learning (see Figure 1). In the acquisition of a typical task, state strength changes occur in the following fashion: first, position responding increases and then decreases to a zero level. As position responding declines, random responding as well as detect responding begin to increase. Finally, the probabilities of random

Table 2. Possible States of Sequential State Theory (SST)*

State	Manifestations**	Type
Detect (D)	+	Attentional
Random (R)	All possible sequences	Attentional
Simple Bias (B)	P(response 1) \neq P(response 2)	Simple Bias
Response Perverservation (P)	II; OO	Sequentially Dependent
Response Alternation (Q)	IO; OI	Sequentially Dependent
Win-Stay; Lose-Shift for Prior Response (F)	I+I, I-O; O+O; O-I	Sequentially Dependent
Win-Shift; Lose-Stay for Prior Response (G)	I+O; I-I; O+I; O-O	Sequentially Dependent
Stimulus Preference/ Aversion or Outcome Clustering (S)	+ +; - -	Sequentially Dependent
Stimulus Alternation or Outcome Alternation (T)	+ -; - +	Sequentially Dependent

*Taken from King and Fobes (in press).

**+ and - indicate correct and incorrect response; I indicates position selected on first trial of a three-trial sequence; O indicates other positions.

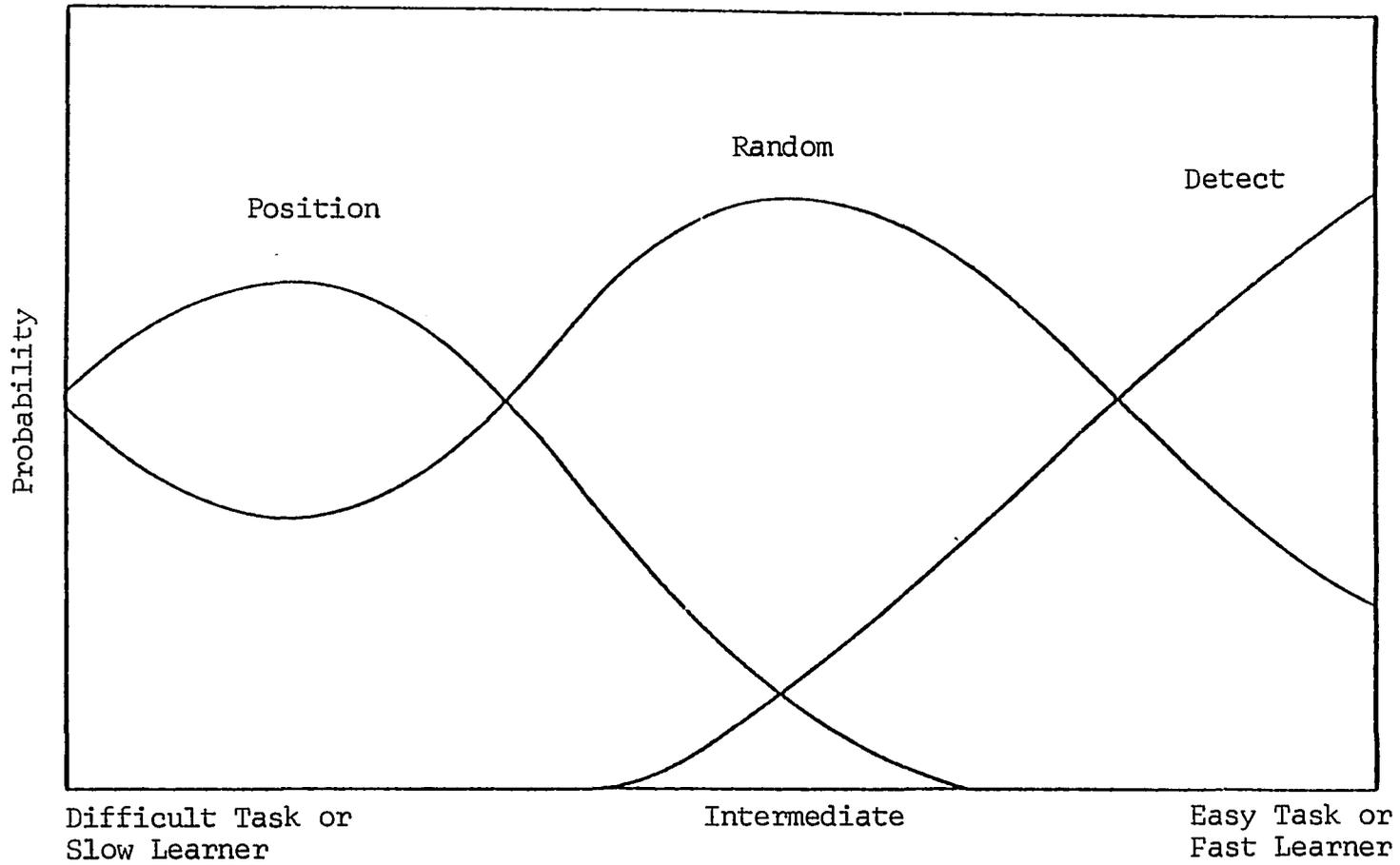


Figure 1. Triphasic Model of Acquisition of Complex Learning

responding and all other nondetect states reach near zero values as detect responding reaches its asymptotic value. Several experiments (King and Fobes, 1975; Scanlon and King, 1976; Smith, King, and Newberry, 1976) were all consistent with the pattern of state strength changes shown in Figure 1. Thus, the stage of random responding, interposed between the extinction of other error producing states and the acquisition of correct or detect responding is assumed to be a manifestation of an active assimilative process with respect to the relevant dimensions of the task. As such, random responding is an integral part of the learning process and immediately precedes evidence of learning as conventionally defined by percentage of correct responses.

CHAPTER 2

PURPOSE

The learning of patterned string problems or delayed-response problems has been amply demonstrated. To date, however, no investigation has been specifically concerned with the effect of partially covering the string arrays on patterned string performance. The present study was designed to test this variable with a new version of the pattern string task. The task typically proceeded as follows:

1. The experimenter raised the opaque screen to allow the subject to view a string problem which was laid out on the stimulus tray of a Wisconsin General Test Apparatus (WGTA); one of the strings was baited with the food cup.
2. A cover was placed over the strings in three different positions for some predetermined delay interval.
3. In the delay period, an overhead light was either on or off.
4. After the delay interval, a Plexiglas screen was raised to allow the subject to pull one of the strings. If the correct string was chosen, the subject could retrieve the reward in the food cup.

Experiments I and II of the present study were designed to determine which part of patterned string array was most important in mediating successful patterned string performance of monkeys. Thus, one independent variable manipulated was the type of cover placement consisting of no cover, middle cover (the central portion of the strings was under cover), or far cover (the end of the strings was under cover). Another independent variable was the duration of the lighted delay interval which was either zero seconds or five seconds.

Some past research on delayed response and DMTS tasks indicated that performance was better when the delay interval was dark than when it was light (e.g., Malmö, 1942; D'Amato and O'Neill, 1971; Etkin, 1972). However, other studies reported opposite results (e.g., King and Clawson, 1966). In addition, past studies showed a disagreement on whether the light occurring at the beginning of the delay interval caused more deleterious effects on learning than did that at the end of the delay interval. Therefore, the delay interval with either light on or off, and the temporal location of the light within the delay interval were effective variables and needed to be studied further. Experiment III of the present study was designed to investigate the effects of the aforementioned two variables on patterned string performance.

CHAPTER 3

EXPERIMENT I

Experiment I was a study of the effect of type of cover placement and duration of lighted delay interval on parallel string performance of squirrel monkeys. Two independent variables, type of cover placement (no cover, middle cover, and far cover) and duration of lighted delay interval (zero seconds and five seconds), resulted in six different testing conditions. A 6 x 6 Latin Square was randomly chosen to assign the subject and the testing condition per day. Thus, each subject received all six testing conditions in different orders.

The results obtained from these six different testing conditions were analyzed by the SST method which revealed the strategies used by squirrel monkeys in performing parallel string problems.

Method

Subjects

Six male squirrel monkeys (Saimiri sciureus) served as subjects in the present experiment. All monkeys were experimentally naive on patterned string problems. They were

maintained on a feeding schedule which kept their body weight at 85% of their ad lib weight.

Apparatus

Testing was manually performed in a modified Wisconsin General Test Apparatus (WGTA). The WGTA was equipped with a stimulus tray, an opaque screen, a Plexiglas screen, and a one-way vision screen. The stimulus tray was made of wood, painted black, and measured 36 cm x 41 cm. The edge of the stimulus tray nearest the subject had five eye-screws, one on the center and four others 7 cm and 13 cm on either side of the center. The opaque screen faced the subject and prevented the subject from viewing the baiting of the strings between trials. The Plexiglas screen was positioned directly behind the opaque screen and raised to allow the subject to respond after a predetermined delay interval. The one-way vision screen was placed between the experimenter and the stimulus tray.

The string problems were formed by a pair of 23 cm silver beaded chains. The chains were attached, by means of snaps, to screw-eyes placed along the edge of the stimulus tray nearest the subject. The food incentive, a small piece of marshmallow, was put in the food cup, the center of which was depressed to secure the food in the central position. The food cup had a circular shape (diameter 3.20 cm) with an eyelet which was connected to the chain by a snap.

The stimulus tray was illuminated by a 60 watt light bulb. A white noise generator was used throughout the experiment to mask external noises.

Adaptation

During adaptation, each subject was given a marshmallow (on the food cup) when it retrieved a single 23 cm string centered on the stimulus tray and attached to the food cup. Then, the experimenter gradually started moving the food cup further and further back until the subject pulled the full string. Each subject had to pull the full string all the way back on all 24 trials of a daily test session to reach the adaptation criteria.

Testing Procedure

During testing, all subjects were given a series of parallel string problems. After the parallel string pattern was viewed by the subject for five seconds, one of three procedures was carried out: (1) a cover was placed over the ends of the strings thereby obscuring the food cup at the end of one string (far cover); (2) a cover was placed over the central portion of the strings allowing the subject to view the food cup but breaking the visual continuity of the strings (middle cover); (3) a cover was placed behind the string pattern thereby not obscuring the subject's view (no cover).

After placement of the cover according to one of the above described conditions, a Plexiglas screen was raised either immediately or after a five-second delay thus allowing the

subject to respond. All combinations of cover conditions and delay intervals led to six possible experimental conditions. Each subject received 24 trials a day, five days a week. All trials on each day were in the same experimental condition. The correct position of any given trial was determined by one of six different 24-trial right-left sequences. All sequences were constructed so that no position was baited for more than three consecutive trials and that each possible three-trial sequence (LLR, RRL, LRL, RLR, LRR, RLL, LLL, and RRR) occurred once. A 6 x 6 Latin Square was randomly chosen to assign the subject and the condition per day. All subjects were tested 60 test days for a total of 1,440 trials.

Hypothesis Analysis

The results were analyzed with the SST method, which was developed by King and Fobes (in press), and was a technique for measuring random and nonrandom components in response sequences. This technique made some improvements over Levine's (1959) technique in that it allowed the subject's hypothesis to change from trial to trial and measured these sequential changes in the data.

SST is a two-stage theory of learning. The first stage is attention (A) which is defined as the summed probabilities of state D (detect) and R (random). All other states reflect some sort of bias, either sequentially dependent or independent. $P(A)$ is therefore the probability of non-biased response.

The second stage is the association stage measured by the bias free measure of learning $(K) = P(D|A)$. A measure K , which is the conditional probability of a detect state given that the subject is attending, can be defined as: $K = P(D|A) = P(D) / [P(DA) + P(R)]$. Therefore, it is a measure of learning independent of all systematic error producing tendencies.

In addition to states D and R , the probabilities of four other states (B , P , F , and S) in SST were also computed. State B is an overall preference of one response over another and is not sequentially dependent on previous responses. State P is a response perseveration or a tendency to repeat the same response regardless of the outcome of the prior response. State F is defined as a win-stay lose-shift with respect to the prior response or is manifested by the response which was correct on the preceding trial. State S is defined as stimulus preference/aversion or is manifested by responses with outcomes same as those on the prior trial. Each of these states (P , F , and S) is the opposite of another state ($P-Q$, $F-G$, and $S-T$) and these state pairs are defined along one dimension. Therefore, only one state within the $P-Q$; $F-G$; and $S-T$ pairs is measured in any particular SST analysis.

The values of $P(+)$ and $P.V.E.$ were also computed. $P(+)$, the probability of a correct response, is related to the probability of state D , $P(D)$, by the following formula: $P(+) = P(D) + 1/2 (1 - P(D))$. $P(+)$ is based on all trials whereas $P(D)$, like the other state probabilities, is based only on trials 2 and 3

of each three-trial sequence. Therefore, $P(+)$ obtained from the above formula is slightly different from $P(+)$ for the entire set of data. P.V.E. is called the proportion of variance explained and is defined in the following formula: $P.V.E. = 1 - \sigma_{op}^2/\sigma^2$ where σ^2 is the variance of the observed value, σ_{op}^2 is the variance between observed frequencies and frequencies from prediction. P.V.E. was first devised by Levine (1965) as a measure of how well his hypothesis strengths obtained from a data set predicted frequencies of 32 different types of three-trial sequences. Under the sequential state theory, P.V.E. became as a measure of how accurate a set of state strengths predicted the frequencies of the same 32 different types of three-trial sequences.

Results

The probabilities of six states and four other values ($P(+)$, $P(A)$, K , and P.V.E.) in the sequential state theory were analyzed with a repeated measure analysis of variance (ANOVA) with the independent variables being the type of cover placement and the delay interval. The main effect for the type of cover placement was significant in state D (detect) ($F(2,10) = 7.84$, $P < .01$) and in correct responding ($P(+)$) ($F(2,10) = 7.73$, $P < .01$). The mean probabilities of the remaining states (R, B, P, F, and S) and values of $P(A)$, K , and P.V.E. revealed no significant differences in three types of cover placement. The probabilities of detect responding and correct responding as a function of type of

cover placement and delay interval are depicted in Figures 2 and 3. Newman-Keuls tests showed that the probability of detect was higher under the no cover condition than under the middle cover condition ($P < .05$) or the far cover condition ($P < .01$). In addition, the probability of correct responding was higher in the no cover condition than in the far cover condition ($P < .05$).

Neither the main effect of delay interval nor the type of cover placement \times delay interval interaction was significant for any state of SST and values of $P(A)$, $P(+)$, K , and $P.V.E.$

Figure 4 shows the strengths of detect, response perseveration, position preference, and random as a function of trials grouped into the five blocks. The increase in the probability of detect over blocks was highly significant ($F(4,25) = 4.74$, $P < .01$). Significant decreases over blocks were also manifested by response perseveration ($F(4,25) = 3.76$, $P < .025$), and random responding ($F(4,25) = 2.92$, $P < .05$). However, the probabilities of the remaining states and the bias free measure of learning, K , did not change over blocks.

Discussion

The foregoing results indicated that squirrel monkeys under no cover condition exhibited a significantly higher probability in the values for the correct response (+) and a detect response (D) than those under cover conditions. In other words, squirrel monkeys performed better in the no cover condition than in the far cover or in the middle cover conditions. The

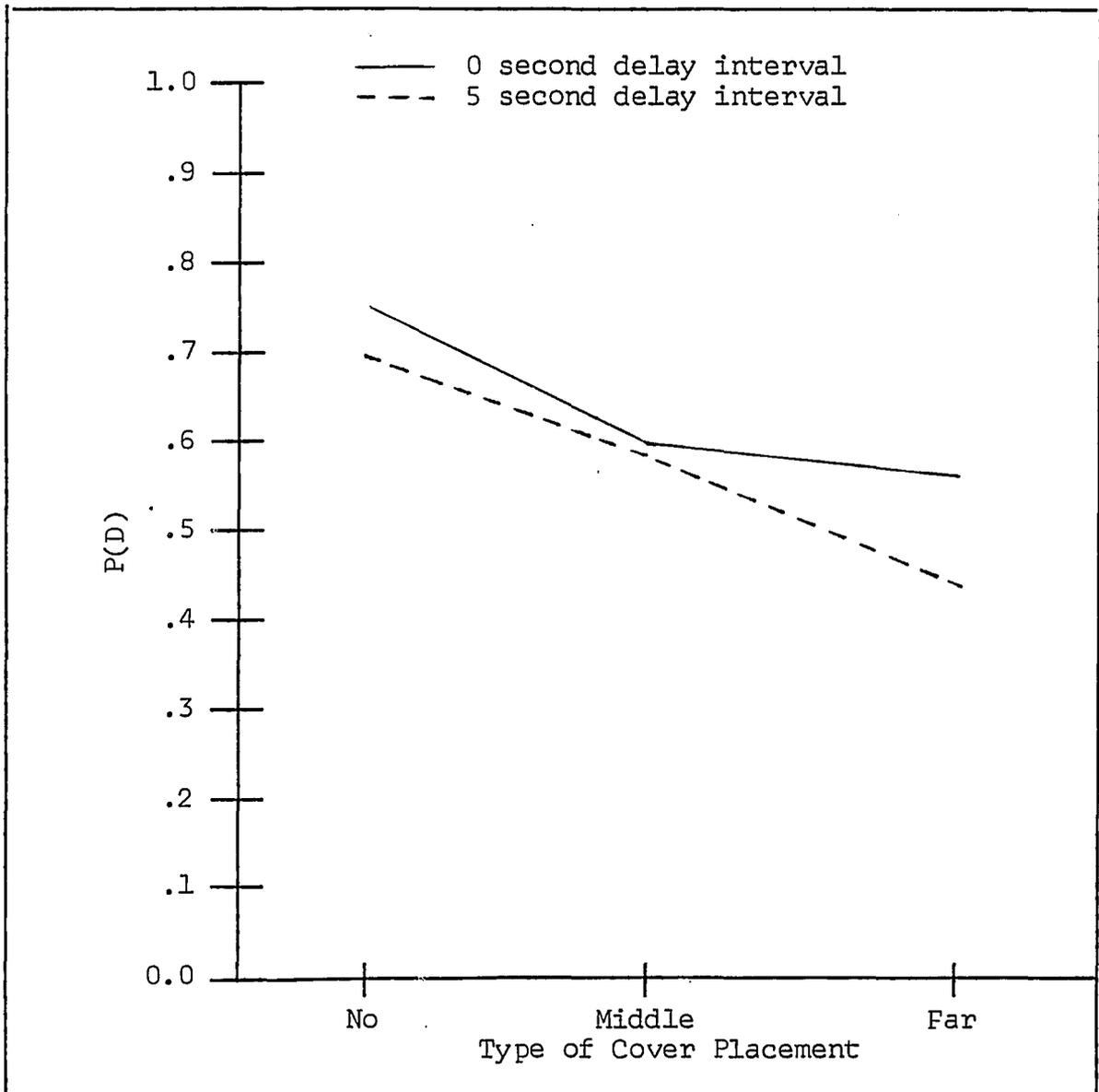


Figure 2. $P(D)$ as a Function of Type of Cover Placement and Delay Interval on Parallel String Patterns

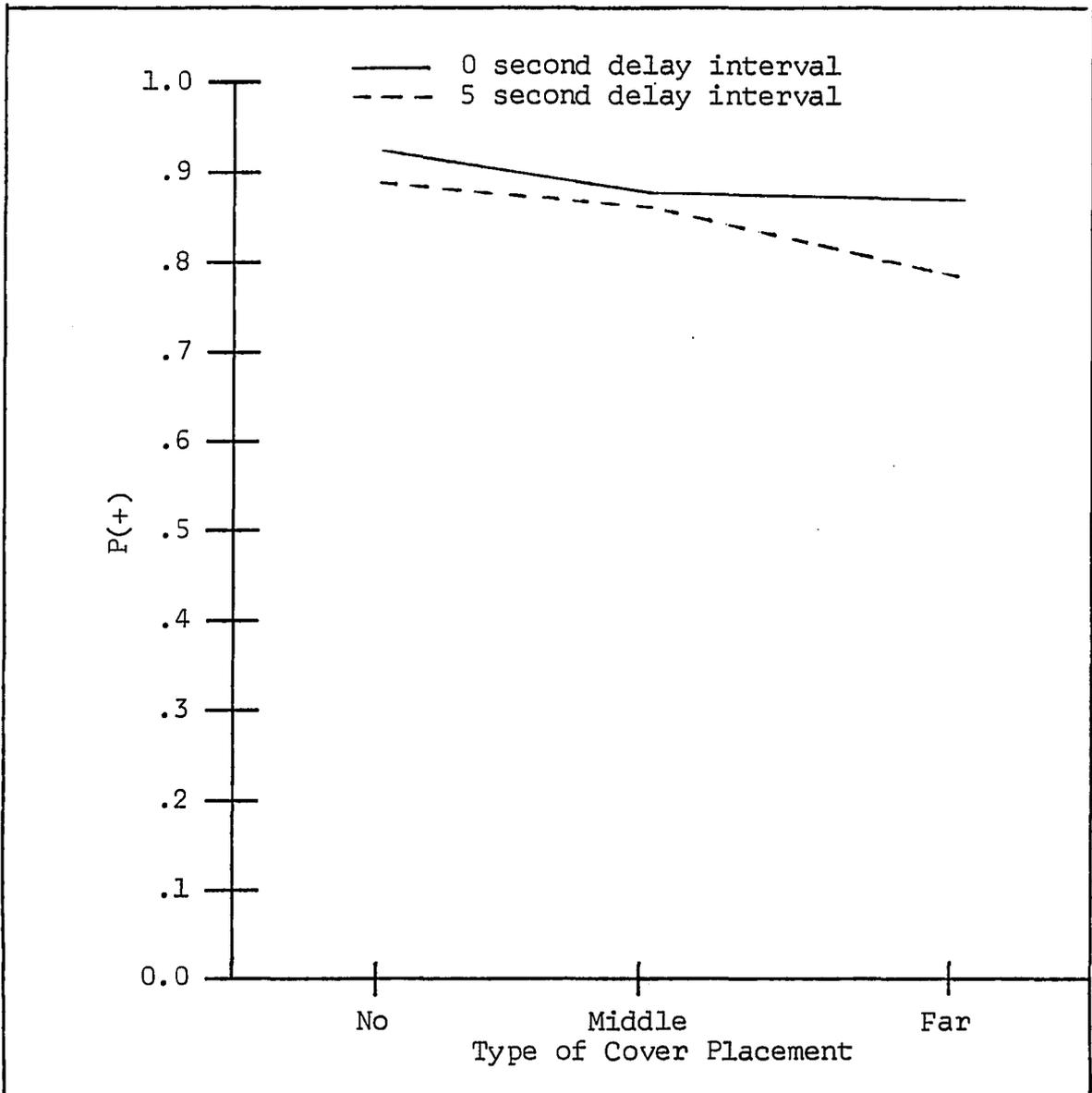


Figure 3. P(+) as a Function of Type of Cover Placement and Delay Interval on Parallel String Patterns

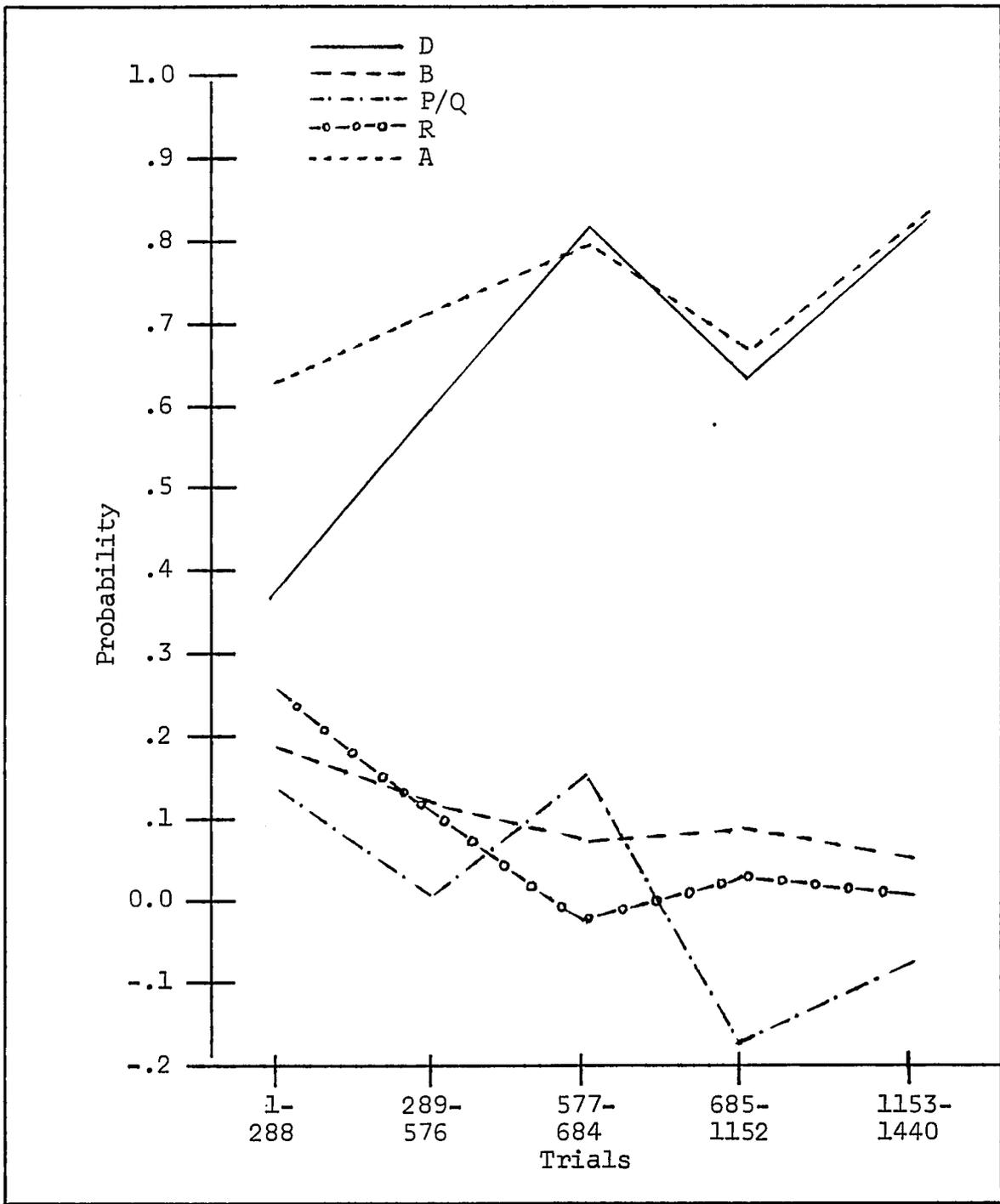


Figure 4. Mean Probability of Values D, B, P/Q, R, and A by Trials

significant increase in the number of errors from the no cover condition to the far cover condition showed that the squirrel monkeys' performance can be disrupted by obscuring the food cup after initial viewing thereby forcing the animal to rely on its memory of the cup's position to make a correct choice. More surprising was the significant difference between the no cover and middle cover condition. This showed that the animals' performance was disrupted by obscuring the middle part of the parallel string pattern while the food cup was still clearly visible. But since the pattern in this experiment was always a parallel one, the middle cover condition obscured no information that was necessary for correct solution. Perhaps, a break in the visual continuity of the strings was disruptive to the squirrel monkeys in spite of the extensive training of the parallel string pattern.

As previously described, the significant effects resulting from the type of cover placement were only in the probabilities of a correct response and state D response. No error tendencies were a function of type of cover placement. In addition, no error tendencies were a function of delay intervals. This lack of error increases indicated that no biases were operating differentially as a function of either type of cover placement or delay interval or a combination of the two.

The subjects manifested relatively high response perseveration and position preference in the first block of trials and then began to decrease in the following block of trials. The probability of a random response decreased from the beginning and

the probability of a detect response increased immediately. Over time detect responses increased in each block of trials. The typical pattern for fast learners from the triphasic model was that response bias (response perseveration and position preference) and random responding both decreased from the beginning and the increase in detect responding was immediate. The data for the squirrel monkeys of this experiment were consistent with the predicted pattern for fast learners contained in SST.

Furthermore, the probability of attention, $P(A)$, did not change over trials. This indicates constant attention since the probability of detect responding goes up and the probability of random response goes down over trials. Therefore, it can be concluded that over trials, there was little loss of bias (non-attention). The change in the probability of response perseveration although significant was small, and seemed to be a change from response perseveration (P) to response alternation (Q). So, the squirrel monkeys were showing high attention from the beginning and the main changes that occurred during testing were an increase in detect responses and a decrease in random responses and these main changes left small change in attention. This response pattern shown by squirrel monkeys was consistent with that of bright capuchin monkeys in sensory discrimination experiment (King and Fobes, in press).

CHAPTER 4

EXPERIMENT II

The data from Experiment I showed that the type of cover placement affected parallel string performance although no significant effect resulted from the duration of delay interval. However, this experiment was designed to investigate whether the same two variables manipulated in Experiment I had an effect on the performance of a more complex problem, crossed-pattern string problems.

In order to answer the same question--which part of patterned string arrays was more important in mediating successful performance--the SST method again was applied to analyze the results obtained from the testing of crossed-pattern string problems.

Method

Subjects

Five male squirrel monkeys used in Experiment I served as subjects in this experiment. The second experiment started immediately after completion of Experiment I.

Apparatus

The apparatus was the same as that described in Experiment I.

Adaptation

All subjects were initially trained on the crossed-pattern strings, 36 trials per day. During this phase, the experimenter baited the food cup and attached it to the rewarded string, then raised an opaque screen and allowed the subject to pull in one of the two strings. No food cup was attached to the nonrewarded string. The noncorrection technique was used. The position of the food cup was determined by a balanced order. Subjects were trained on this pattern until they attained a criterion of 32 out of 36 correct responses in two consecutive days.

Testing Procedure

The testing procedure was the same as that described in Experiment I except that crossed-pattern string problems were presented instead of parallel-patterned string problems. Each subject was given all six testing conditions which were formed by a combination of three different types of cover placement and two delay intervals. All subjects received 36 trials per day over 42 test days for a total of 1,512 trials.

Results

A repeated 3 x 2 analyses of variance was conducted with type of cover placement and delay interval as the independent

variables and probabilities of each state in SST the dependent variables. The main effect of type of cover placement was significant only for state B, position preference ($F(2,8) = 6.09$, $P < .025$). The probability of position preference (B) as a function of type of cover placement and delay interval is shown in Figure 5. Newman-Keuls tests revealed that the subjects during the middle cover condition manifested stronger position preferences than during the no cover condition ($P < .01$) or during the far cover condition ($P < .01$). The main effect of delay interval was also significant for state P which was defined as response perseveration ($F(1,4) = 10.09$, $P < .05$). Figure 6 shows that the squirrel monkeys manifested more response perseveration with zero-second delay than with five-second delay on the crossed string pattern. In addition, the interaction between type of cover placement and delay interval was significant for state F, win-stay lose-shift for position ($F(2,8) = 4.47$, $P < .05$) and is depicted in Figure 7. No other main effects or interactions reached statistical significance.

Separate ANOVAs were used to analyze the values of $P(+)$, $P(A)$, K , and $P.V.E.$ $P(+)$, the probability of a correct response, is measured by the following formula: $P(+) = P(D) + 1/2(1 - P(D))$. The values of $P(+)$ for each testing condition were ranged from the mean value of .81 for five second-middle cover condition to the mean value of .85 for zero second-no cover condition. The ANOVA on the value of $P(+)$ revealed no significant main effects nor interaction effect. Again, neither the type of

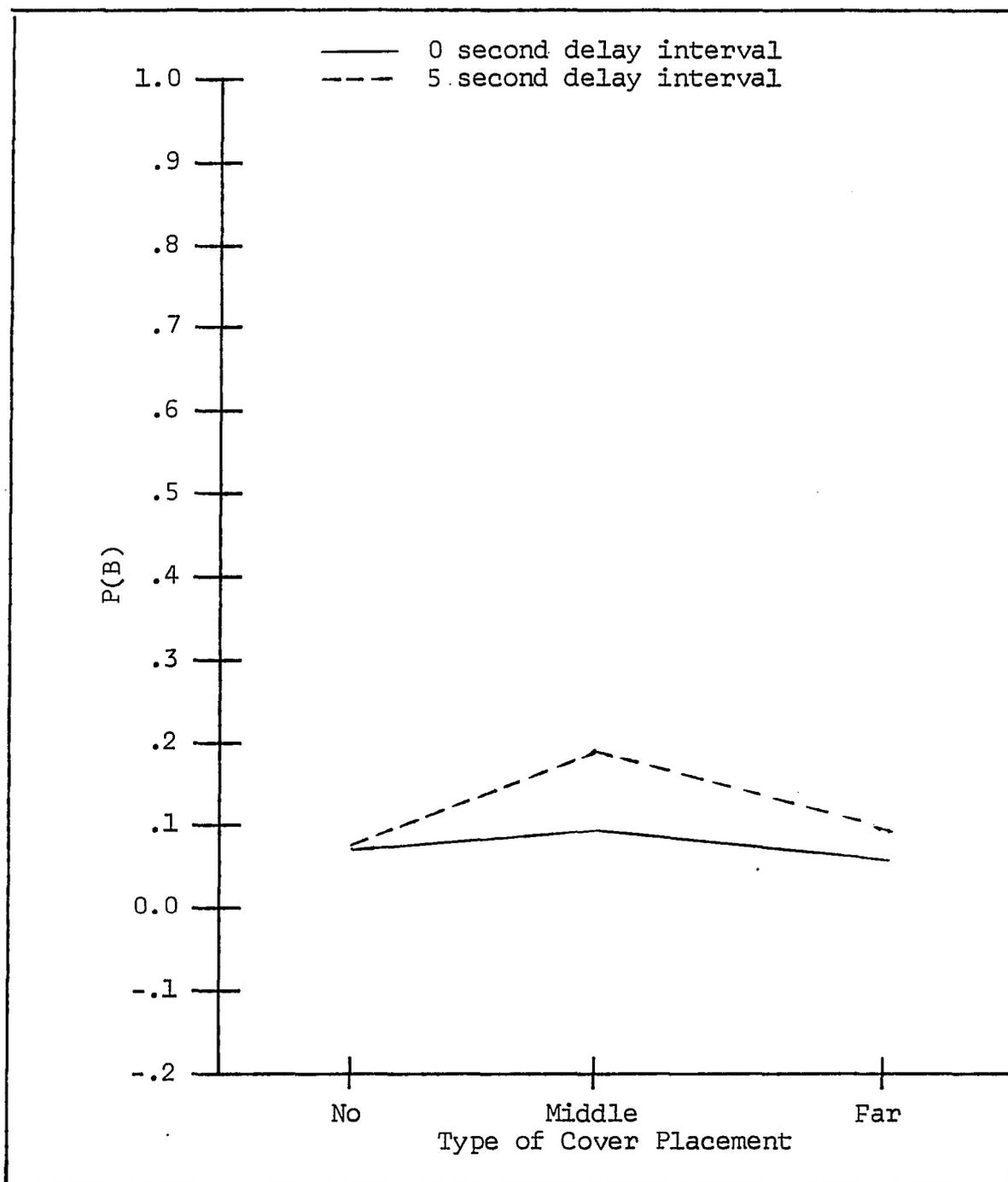


Figure 5. $P(B)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns

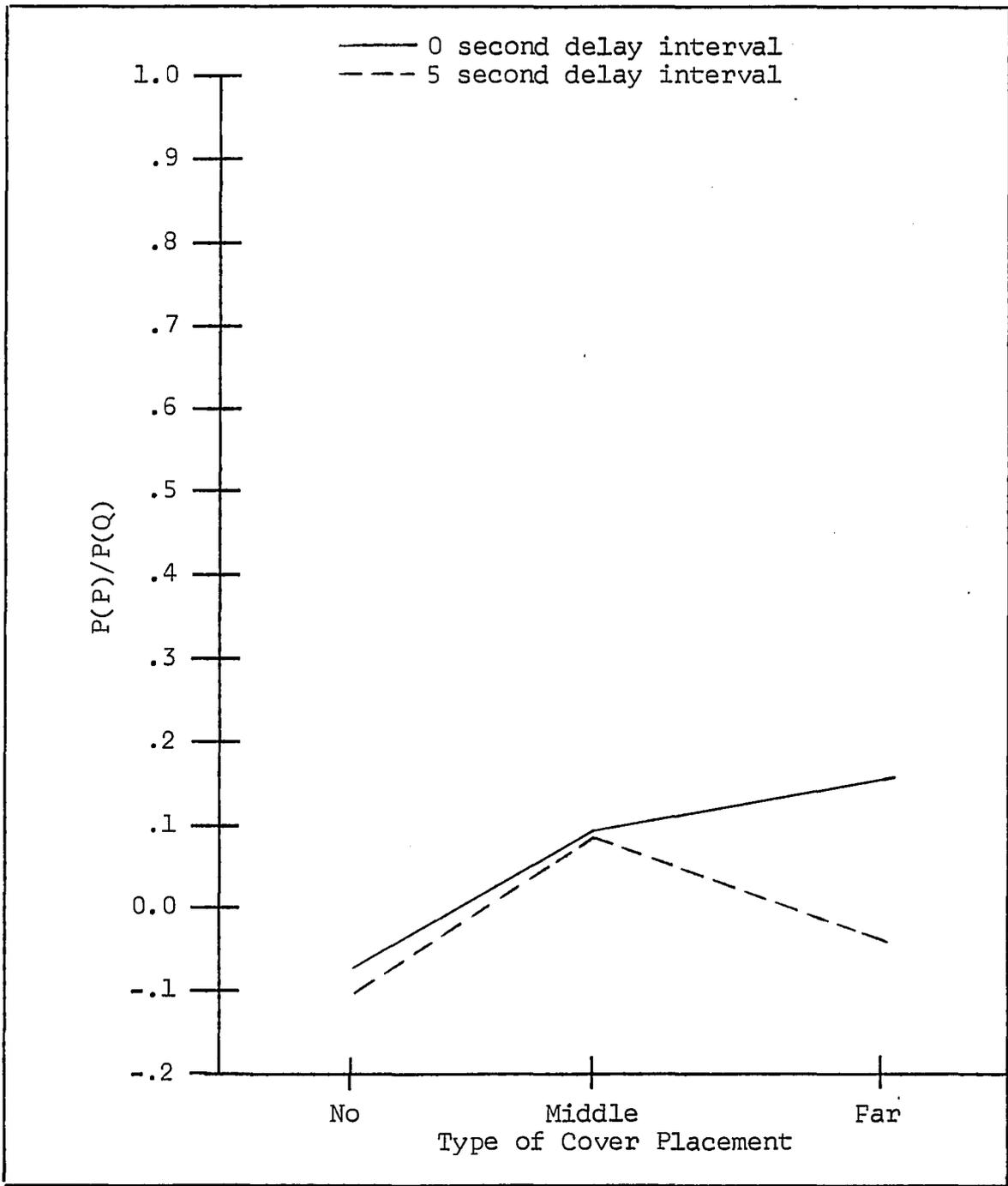


Figure 6. $P(P)/P(Q)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns

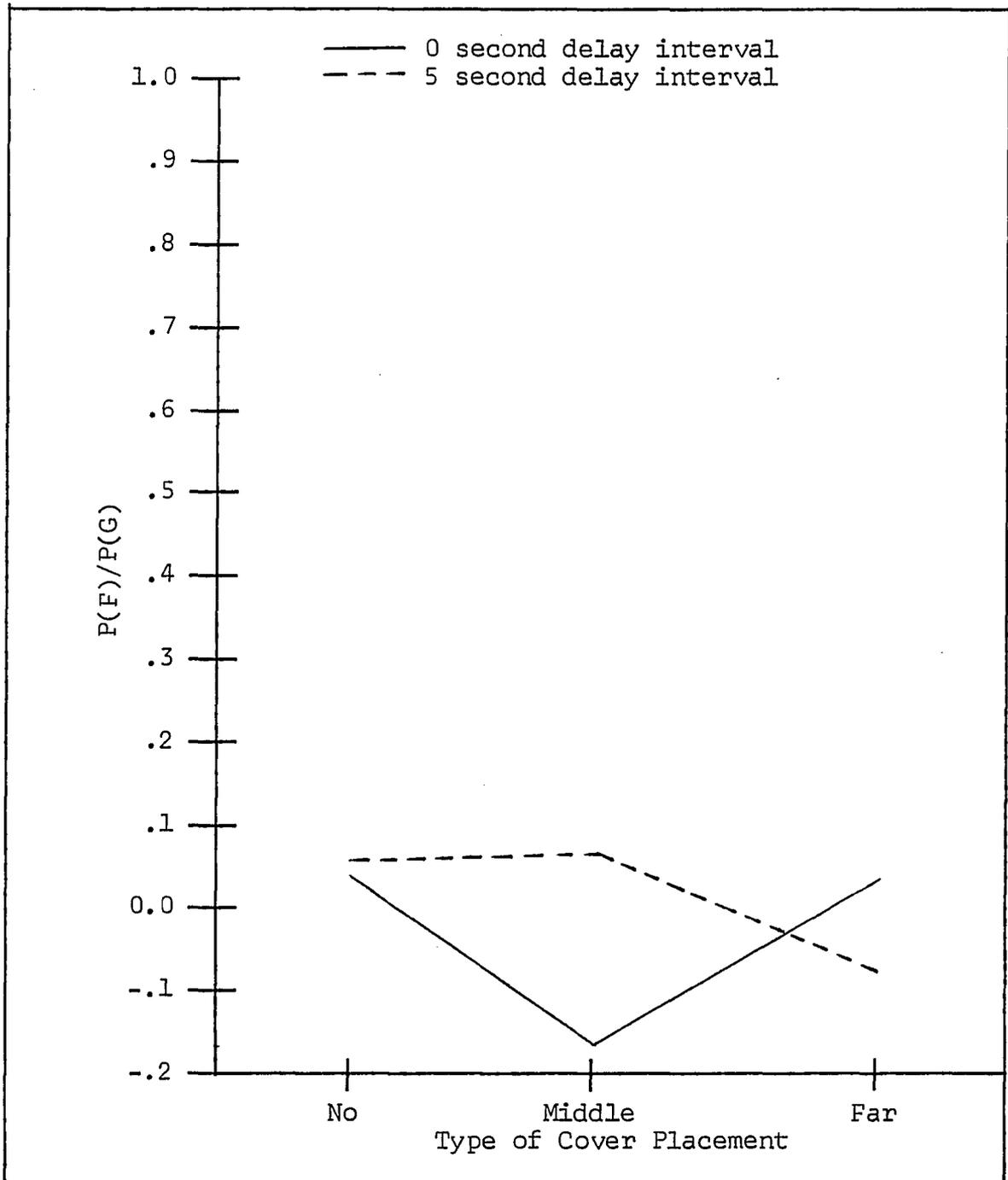


Figure 7. $P(F)/P(G)$ as a Function of Type of Cover Placement and Delay Interval on Crossed String Patterns

cover placement nor the delay interval produced significant effects on the values of P(A), K, and P.V.E.

The total of 1,512 trials was divided into seven blocks, 216 trials each block. One-way analyses of variance computed on each state of SST indicated a significant block effect on state P, response perseveration ($F(6,34) = 2.64, P < .05$). Response perseveration showed a constant increase-then-decrease trend over blocks. The probabilities of the remaining states did not change over blocks. One-way analyses of variance were also conducted on four other values (P(+), P(A), K, P.V.E.). The probability of correct responses, P(+), was extremely high and the mean value of P(+) was .84. Unfortunately, no significant block effect was shown on the probability of correct responses. None of the ANOVAs with the remaining values as the dependent variables were significant thereby indicating that these three values did not change over blocks.

Discussion

The results indicated that three different types of cover placement over the strings during the delay resulted in significant effects on the probability of position preferences. The squirrel monkeys manifested more position preferences on the crossed string pattern during the middle cover condition than during the no cover condition or during the far cover condition. Unlike Experiment I, a cover placed in the middle part of the strings obscured the information that was necessary for correct

solution. Thus, obscuring the central part which breaks the visual continuity of the strings causes more position preference errors. So, in Experiment II, the middle cover condition seemed to be causing some difficulties for the monkeys. This is shown by the significant increase in position responses (B) for middle cover condition. This is also shown by the increase in P for middle cover condition under five-second delay. It becomes apparent that obscuring the central part of the pattern has a more deleterious effect on crossed string performance than on parallel string performance. Therefore, this shows one advantage of SST, it reveals a subtle difficulty caused by middle cover placement in the crossed string pattern, which was not revealed by the proportion of correct response. It would be expected that middle cover placement should have a more serious effect on crossed string performance than on parallel string performance. The reason is that squirrel monkeys probably have a strong tendency to reach for the string nearest the food cup. In crossed string patterns this strategy will lead to errors since the string closest to the food cup is always incorrect. However, in the parallel pattern the string closest to the food cup is always the correct one. Therefore, obscuring the center part of the display should cause a deterioration of performance on crossed but not on parallel string display. Thus, the animal must see the center part of the crossed string display in order to get the information indicating that the string closest to the food cup should not be pulled. On the other hand, when a parallel pattern is

presented, seeing the middle part of the display is less important since the strategy of reaching for the nearest food cup will suffice to make a correct response.

As shown in Figure 6, the data showed that the squirrel monkeys during zero-second delay interval demonstrated more response perseveration than did those during five-second delay interval on the crossed string pattern. Less perseveration occurring during the five-second delay may reflect a loss of memory for the particular response made on the previous trial.

Although the probability of response perseveration (P) was significant over blocks, none of the probabilities of the remaining states changed over blocks. This result was due to a fact that the probability of correct responding, $P(+)$, was so high to begin with.

CHAPTER 5

EXPERIMENT III

Experiments I and II demonstrated that three types of cover placement produced significant effects on parallel- and crossed-string performance. Experiment III used only the crossed-string pattern with a cover placed over the ends of the strings. The purposes of Experiment III were to determine (1) whether the monkeys performed better when the light was turned on during cover placement in the delay interval than when the light was turned off during cover placement in the delay interval and (2) the temporal location of covering within the delay interval resulted in more disruptive effects on patterned string performance. Ten experimental conditions resulted from a combination of light/dark delay and five different locations of covering the ends of the strings in 12-second delay interval, and a control condition were given to six cebus monkeys. The SST method was used to analyze the results and to determine what response strategies underlying the houselight and the beginning-end effects.

Method

Subjects

The subjects were six capuchin monkeys (Cebus apella). Two of them were females and four were males. All subjects were experimentally naive on patterned string problems. All were maintained on a feeding schedule which kept their body weight at 85% of their ad lib weight. Experiment III followed the second experiment after a period of approximately three months.

Apparatus

The apparatus was almost the same as that described in Experiment I. In lighted delay intervals, a 60 watt light bulb located at the top of the stimulus tray was turned on, while in dark delay intervals the light was extinguished.

Adaptation

As in Experiment II, each subject was initially trained the crossed-pattern strings presented on a WGTA tray. All subjects were trained on this pattern until they attained a criterion of 21 correct responses during the 24 daily trials for two consecutive days.

Testing Procedure

All subjects were presented with a series of crossed-pattern string problems. An opaque screen was used to prevent the subject from viewing the strings while the experimenter baited the food cup. After the opaque screen was raised, a

Plexiglas screen prevented the subject from responding before the delay interval was completed. The delay interval was always 12 seconds followed by raising of the Plexiglas screen with far cover in place. At the end of 12 seconds the light was turned on under all 11 conditions except that the light was already on. After the crossed-pattern strings were viewed by the subject, one of the following 11 conditions prevailed during the 12-second delay interval: (1) A cover was placed over the ends of the strings obscuring the food cup for four seconds, then the cover was taken away for eight seconds. At the end of eight seconds the cover was placed over the ends of the strings again. At this time a Plexiglas screen was raised to allow the subject to respond. This completed one trial. (2) A cover was placed behind the string pattern for four seconds then placed over the ends of the strings for four seconds, then taken away. At the end of four seconds the cover was placed over the ends of the strings again. (3) A cover was placed behind the string pattern for eight seconds then placed over the ends of the strings for four seconds. (4) A cover was placed over the ends of the strings for eight seconds then taken away for four seconds. At the end of four seconds the cover was placed over the ends of the strings again. (5) A cover was placed behind the string pattern for four seconds then placed over the ends of the strings for eight seconds. (6) The procedure of condition (1) was repeated, however, the overhead illumination was turned off when the cover was placed over the ends of the strings for the first four seconds.

(7) The procedure of condition (2) was repeated, however, the overhead illumination was turned off when the cover was placed over the ends of the strings during the middle four seconds.

(8) The procedure of condition (3) was repeated, however, the overhead illumination was turned off for the last four seconds.

(9) The procedure of condition (4) was repeated, however, the

light was turned off during the first eight seconds. (10) The

procedure of condition (5) was repeated, however, the light was

turned off during the last eight seconds. (11) The control con-

dition was the presentation of the strings without a cover and

with continuous lighting for 12 seconds before the raising of the

Plexiglas screen.

The position of the rewarded string on each trial was determined by one of six different 24-trial right-left sequences. All sequences were constructed so that no position was baited for more than three consecutive trials and that each possible three-trial sequence occurred equally often in a daily test session. A randomized 11 x 10 Youden Square was used to assign the subject and the condition for each day. Each subject received 24 trials a day, five days a week. All trials on each day were in the same condition. Each subject received 110 test days for a total of 2,640 trials.

Results

The probability of each state in SST was analyzed with a two factor (light/dark delay x temporal location of covering),

within subjects analysis of variance. There was a significant difference in the probability of state F, win-stay lose-shift for prior response, on light/dark delay during cover placement ($F(1,5) = 6.67, P < .05$). Probabilities of state F as a function of light/dark delay is shown in Figure 8. As shown in Figure 8, the subjects manifested win-stay lose-shift for prior response in light delay intervals whereas manifested win-shift lose-stay for prior response (state G) in dark delay intervals during a cover placed at the end of the strings.

Probabilities of random responses, $P(R)$, as a function of light/dark delay is shown in Figure 9 and was also significant ($F(1,5) = 8.63, P < .05$). The light delay interval produced higher probabilities of random responses than did the dark delay interval regardless of the temporal location of covering the strings in the delay interval. Neither the main effects nor the interaction between light/dark delay and location of covering the strings were significant on the remaining states of SST.

The values of K , $P(A)$, $P.V.E.$, and $P(+)$ were also analyzed with a two factor within subjects ANOVA. The temporal location of covering the strings resulted in significant differences for K , a measure of learning independent of all systematic error producing tendencies ($F(4,20) = 2.88, P < .05$). The effect of temporal location of covering the strings on K is shown in Figure 10. According to Newman-Keuls tests, regardless of light or dark conditions, the subjects showed greater K when the cover was presented in the beginning four-second delay interval

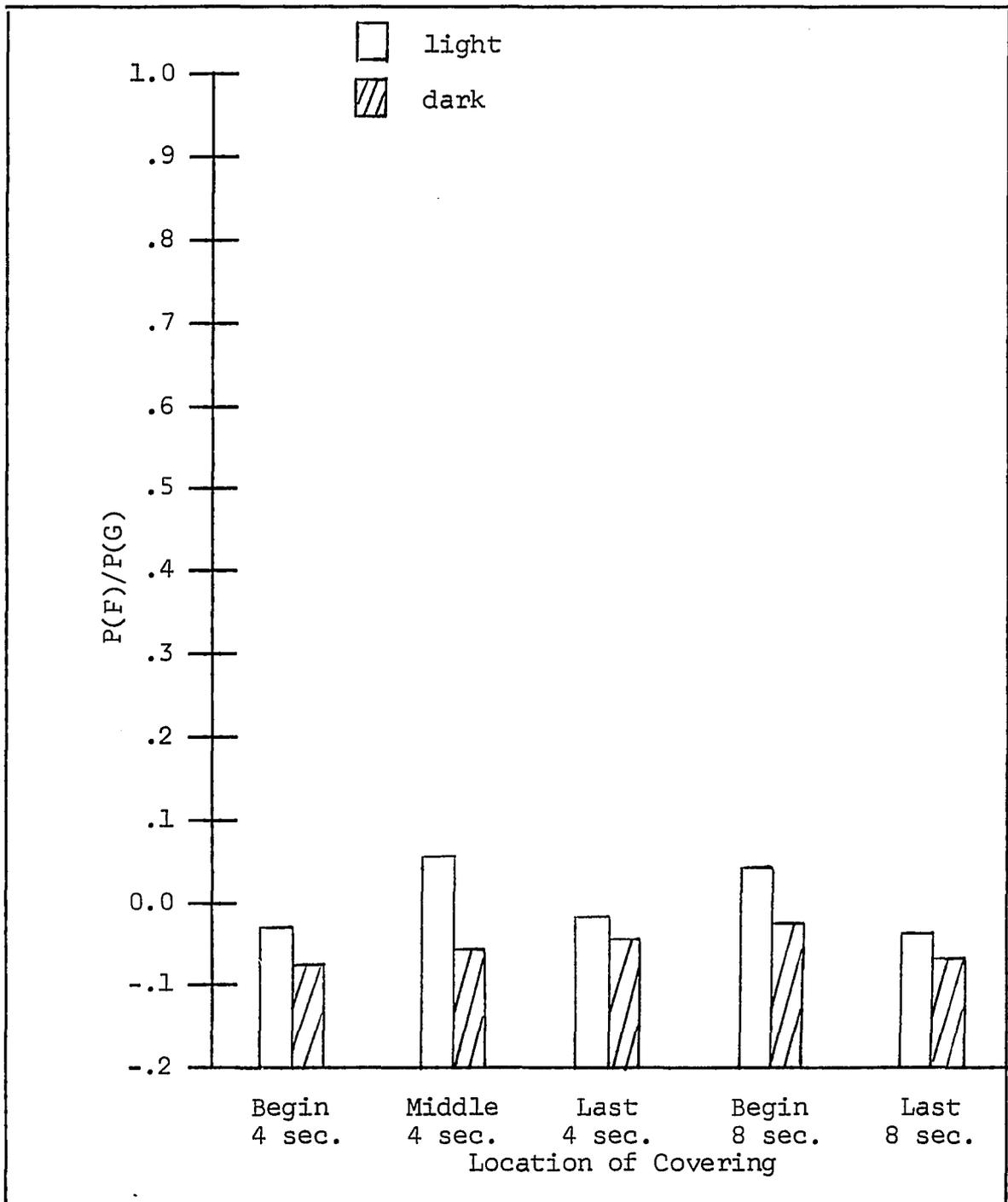


Figure 8. $P(F)/P(G)$ as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns

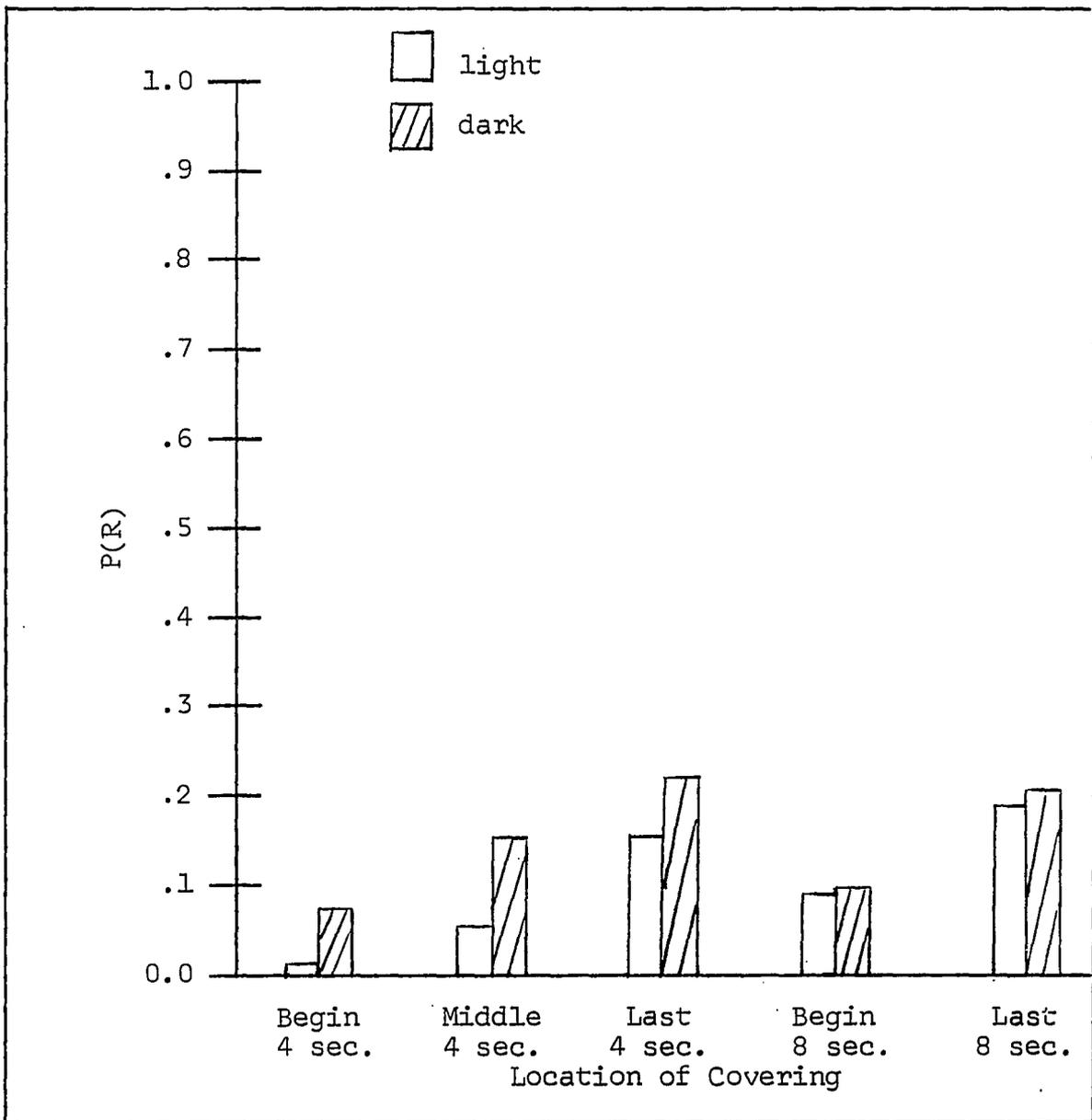


Figure 9. $P(R)$ as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns

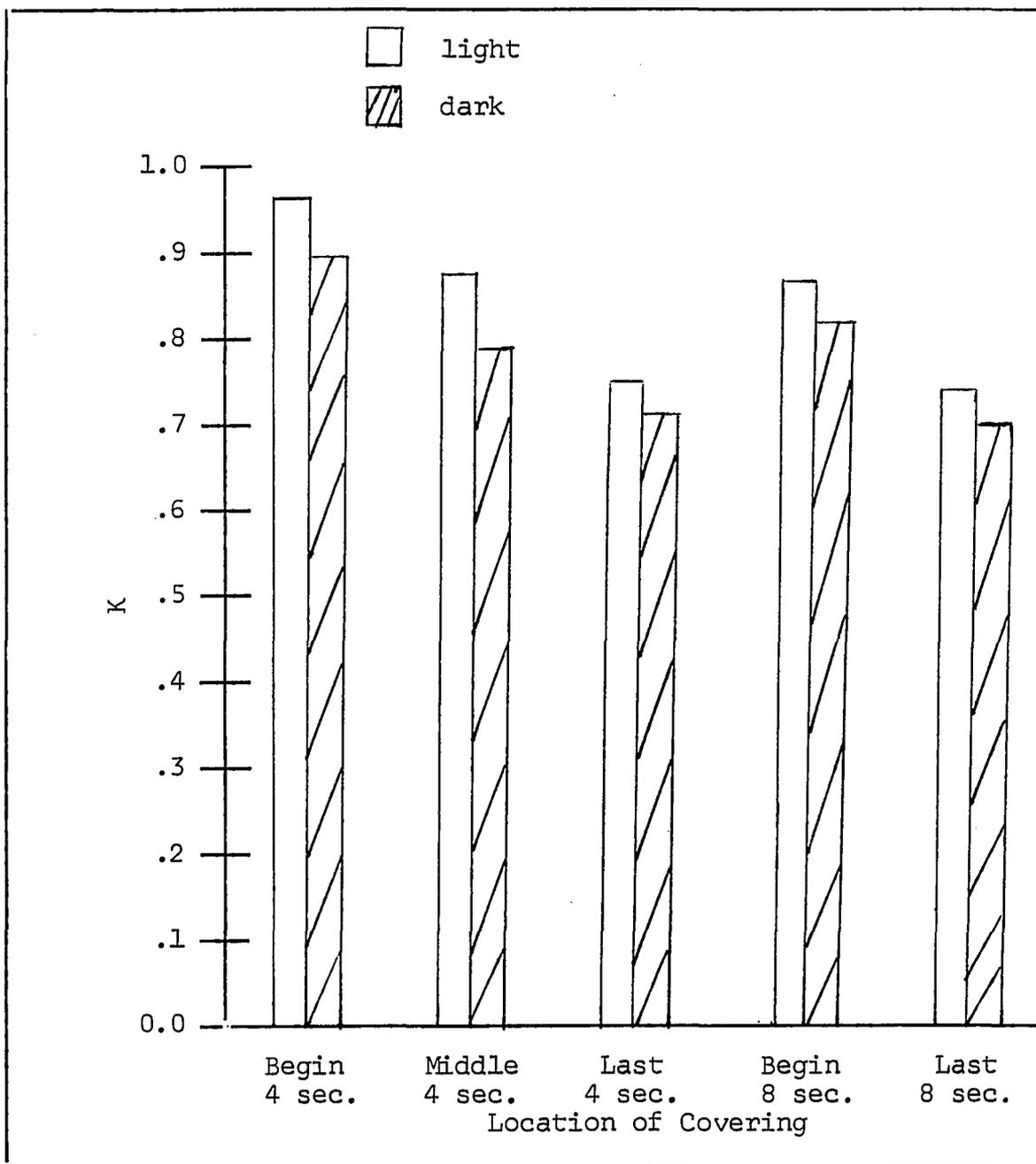


Figure 10. K as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns

(conditions 1 and 6) than when the cover was presented in the end four-second delay interval (conditions 3 and 8) ($P < .05$) or when the cover was presented in the end eight-second delay interval (conditions 5 and 10) ($P < .05$). Furthermore, the effect of light/dark delay on K was significant ($F(1,5) = 6.86$, $P < .05$) and is also depicted in Figure 10. No matter what the temporal location of covering the strings was, the lighted delay condition produced a higher probability of bias free measure of learning (K) than the dark delay condition.

The temporal location of covering the strings during the delay resulted in significant difference on P(+), the probability of a correct response ($F(4,20) = 4.95$, $P < .01$). The effect of the five temporal location of covering the strings was analyzed by the Newman-Keuls test to compare the means of the different scores for each temporal location of covering. A cover placed at the end eight seconds of 12-second delay interval produced fewer correct responses than a cover placed at the beginning four seconds ($P < .01$), at the middle four seconds ($P < .01$), or at the beginning eight seconds ($P < .01$) (see Figure 11). No main effect or interaction effect reached significance for P(A) or P.V.E.

Comparison of probabilities on each state of SST between the combined experimental conditions and the control condition revealed a significant difference on P(D), the probability of detect ($t(5) = 5.11$, $P < .01$; two-tailed test). In addition, the difference of P(A) and P(+) between the experimental conditions and the control condition reached significance

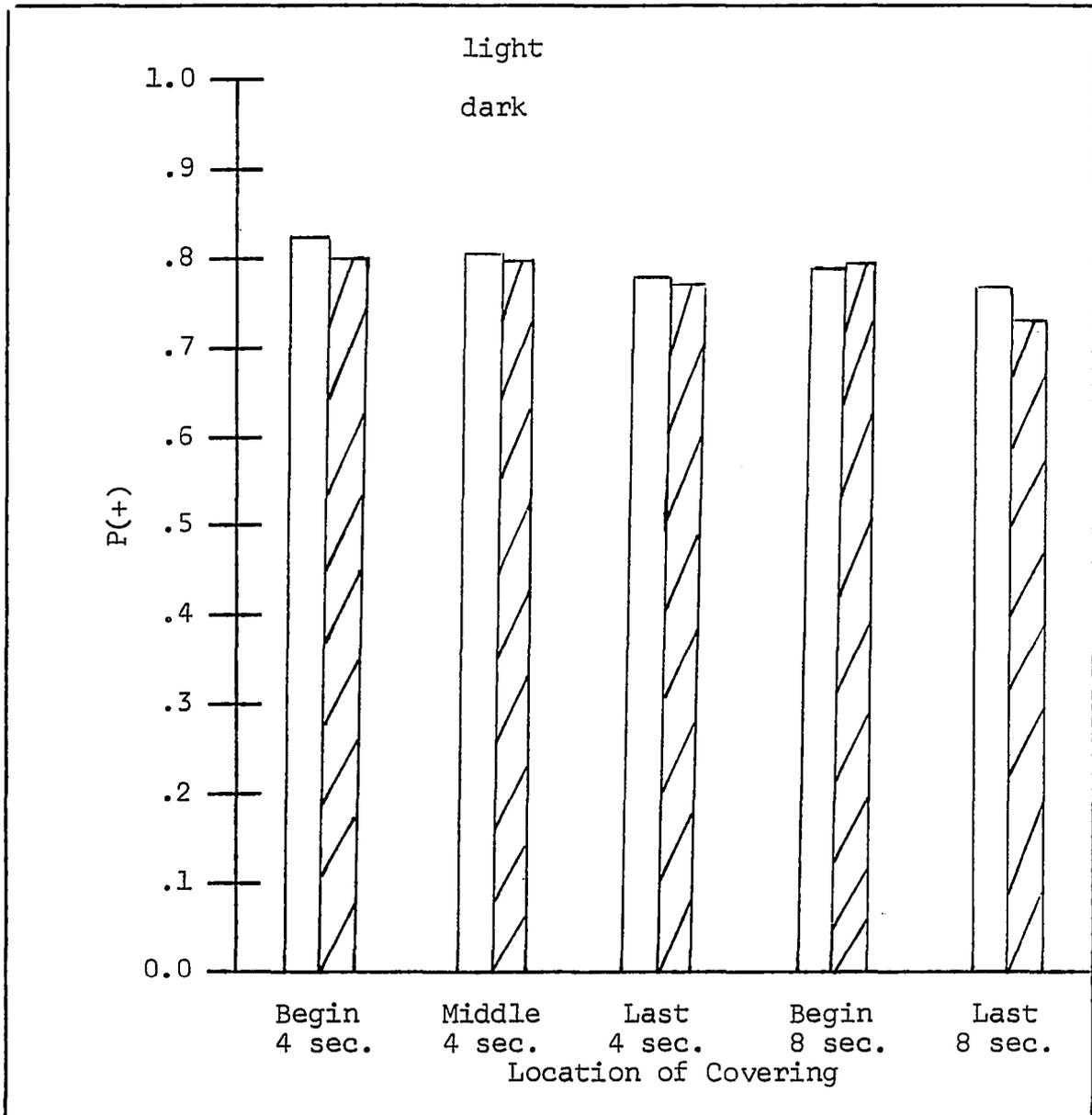


Figure 11. P(+) as a Function of Location of Covering and Light/Dark Delay on Crossed String Patterns

($t(5) = 4.32$, $P < .01$; and $t(5) = 4.85$, $P < .01$; respectively, two-tailed tests). Figure 12 depicts mean values for $P(D)$, $P(A)$, and $P(+)$ for the pooled performance on all experimental conditions with some cover and for performance on the control condition with no cover nor intervening darkness. As shown in Figure 12, the subjects in the control condition manifested more detect, correct responding and attention than did the subjects in the combined experimental conditions. However, there was no significant difference between the control condition with no cover nor intervening darkness and the combined experimental conditions on the remaining states of SST and value K .

$P(+)$, the probability of correct response, in the testing phase increased from a mean of .760 in the first 528-trial block to a mean of .899 in the final 528-trial block; however, this increase was not significant. The remaining states of SST and the values of $P(A)$ and K did not change significantly over blocks.

Discussion

The foregoing results indicated that there were significant differences between light and dark delay conditions on the probabilities of random responses (R) and bias free measure of learning (K). However, the probabilities of detect (D) and correct responding were not significantly different between light and dark conditions. Capuchin monkeys manifested more random responses in the dark delay condition than in the light delay

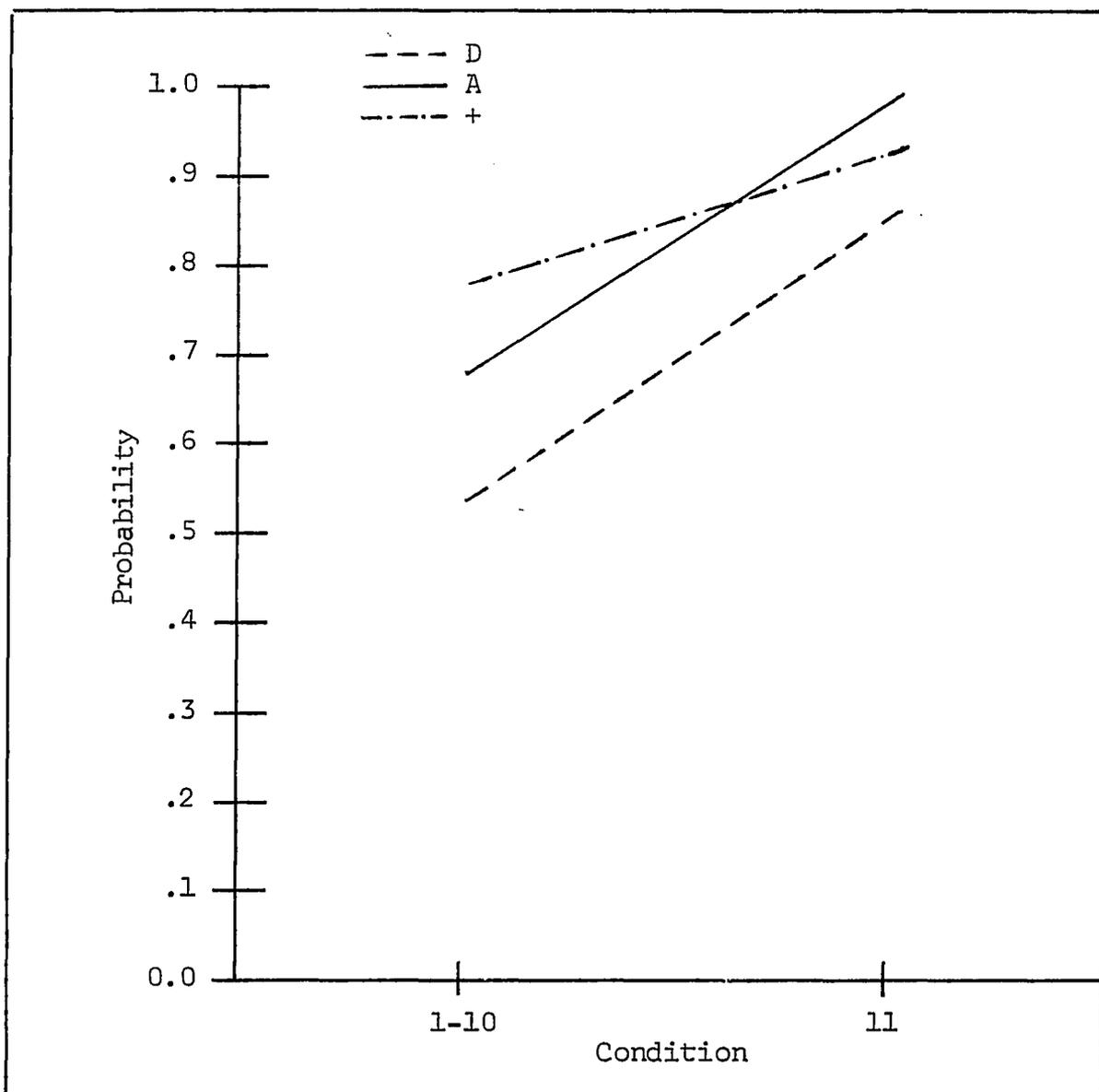


Figure 12. Probability of Values D, A, and + as a Function of Conditions 1-10 and Condition 11 (Control Condition) on Crossed String Patterns

condition. This resulted in lower K values in the dark delay condition than in light delay condition. Also, capuchin monkeys manifested state F (win-stay lose-shift for prior response) during dark delay interval. It seems that darkness caused a non-significant decrease in nonrandom error producing tendencies (P+S+B+F) and a significant increase in random responses. So, perhaps this could explain some of the conflicting previous results on the effect of darkness during a delay interval. If non-random error producing tendencies are high to begin with then darkness will help overall performance. If these tendencies are low, perhaps because the subject is already well-trained, then darkness may decrease overall performance because of the increase in random responses. In either case, we would expect K to decrease in dark. Thus, during the light delay there is a decrease in random responses but an increase in K. The values of P(+) in the light and dark delay conditions were not significantly different due to a compensatory contribution of P(R) and K, i.e., P(R) was lower causing a higher value of K in the light condition than in the dark condition.

The equivalent performance of the capuchin monkeys during light and dark delays was not consistent with several previous studies indicating that animals performed more poorly with lighted delays on the delayed matching-to-sample task (e.g., D'Amato and O'Neill, 1971; Etkin, 1972; Grant and Roberts, 1976). The result was also inconsistent with prior studies showing that squirrel monkeys performed better under light conditions on

simple delayed response (King and Clawson, 1966; King et al., 1968). The memory-loss hypothesis and the temporal discrimination hypothesis predicted that darkness always helps performance. However, the present result did not support these two hypotheses.

Regardless of light or dark delay conditions, the poorest performance occurred in conditions 5 and 10 which were conducted with a cover placed at the end eight seconds of 12 seconds delay interval. This result was consistent with Kendrick's (1980) indirect delayed response study which indicated that correct responses were lower for the condition in which the end of the delay interval was conducted in darkness. Both Kendrick's result and the results of the present experiment supported the consolidation or pre-severation of after-image hypothesis which predicted that darkness introduced at the beginning of the delay period improved performance. However, the present finding conflicted with the result of Etkin's (1972) study using different experimental paradigm which indicated that darkness presented at the beginning of a delay interval caused more disruption than did it at the end of the interval.

The apparent conflict between the results of the present experiment and Etkin's study can be resolved if one assumes that there was inflow of information during 12 seconds of pattern string presentation. In Etkin's delayed matching-to-sample study no such information inflow occurred. The subjects probably did not receive information equally during all parts of the delay

interval. If performance is better when a cover is placed at the beginning of a delay interval than when it is placed at the end of a delay interval, then information received in the late part of the delay interval is used more efficiently than that received in the early part of the delay interval. That the poorest performance occurred when the cover was in place during the last eight seconds of a delay suggests that information received during the later part of the delay is more important in mediating successful performance.

Capuchin monkeys in the control condition with no cover nor intervening darkness had a higher percentage of correct responses than did the subjects in the combined experimental conditions of light-dark with the cover. This finding was expected and suggests that total exposure time is a potent variable affecting primates' performance on patterned string problems.

CHAPTER 6

GENERAL DISCUSSION

The first question this study was designed to answer was which part of patterned string array is most important in mediating successful patterned string performance. The finding in Experiment I indicated that the far cover condition produced fewer correct responses than the no cover condition on parallel string patterns. The result in Experiment II showed that on crossed-string patterns the middle cover condition caused more position preferences than the no cover condition. Thus, far cover placement had the most deleterious effect on parallel string performance whereas middle cover placement had the most deleterious effect on crossed-string performance. This indicates that seeing the central portion of the display is more important on crossed-string performance than on parallel string performance. The reason is that the strategy of pulling the string closest to the food cup is correct on parallel string patterns but not correct on crossed-string patterns. Therefore, seeing the central part of the string display rather than seeing the food cup at the end of the string is more important for crossed-string patterns.

The second question addressed in this study was how the temporal location of covering during light or dark delay affected

patterned string performance. The inconsistency of results between the third experiment of this study and several other studies is explained by the speculation that perhaps the subjects do not receive information equally during all parts of the delay interval. Thus, the time during the delay interval when relevant information is utilized most efficiently is no doubt an important variable determining probabilities of correct choice. A study conducted by Levere and Bartus (1971) used rhesus monkeys with simultaneous two-choice discrimination problems. Their procedure involved a one-second preresponse stimulus observation period which was divided into two 500-millisecond segments. During the early and late parts of observation period, either relevant or irrelevant information was presented. When the subjects were provided with relevant information during the early segment, acquisition proceeded at a very rapid rate and was little influenced by the quality of the information presented during the late segment. If, on the other hand, irrelevant information was presented during the initial segment, acquisition was significantly retarded, even when relevant information became available during the second segment. Thus, the monkey has a tendency to use only the early preresponse information to determine its choice and neglects later information even though this later information is closer to the choice response and may even be more relevant to the efficient solution of discrimination problems. Furthermore, this tendency to use the initially relevant information for correct

choices occurred not only in acquisition but also in sophisticated subjects (Levere and Bartus, 1972).

The result in the third experiment indicated that a cover placed at the terminal four or eight seconds of a 12-second delay interval (conditions 3, 5, 8, and 10) caused more disruption on performance than a cover placed at the beginning four or eight seconds (conditions 1, 4, 6, and 9). In other words, relevant information (the fully visible pattern) presented at the end of a delay interval (conditions 1, 4, 6, and 9) was used more efficiently than that presented at the beginning of a delay interval (conditions 3, 5, 8, and 10). It seems that capuchin monkeys make a correct choice on the basis of information received at the end of a delay interval. This result, seemingly conflicting with that of Levere and Bartus may be due to task difference and time interval difference for presentation of information. In Levere and Bartus' study, regardless of information relevance, the information was always presented in a fixed 500-mseconds period; while in the present study, the time interval for information presentation was varied by the testing condition and was longer (four or eight seconds). Unlike the rhesus monkeys in the Levere and Bartus' study, the capuchin monkey in the present experiment responded mainly to information presented at the end of a delay interval. If relevant information was followed by irrelevant information (a cover placed at the end of the string but with some part of the string protruding from the cover), then it always caused a serious decline in performance. Also, if

irrelevant information was followed by relevant information, then it always improved performance. Therefore, relevant information presented at the end four or eight seconds of a delay interval would be expected to increase performance more than irrelevant information presented at the end four or eight seconds.

The discrepancy in the results of the present study and that of Levere and Bartus could be attributed to several differences in the two studies. First, one involved a pattern string problem and the other was a simultaneous discrimination problem. Secondly, the present study used longer delays (at least several seconds) and was designed as a test of memory; in contrast, the Levere and Bartus study used one-second prerresponse interval and was primarily a test of short term attention. Finally, a species difference, one with capuchin monkeys and the other with rhesus monkeys, was probably not important. Thus, it can be concluded that the results in both studies are complementary with each other. The present study demonstrates that in long delays, animals use information closest to the choice response and this would be expected where memory causes a problem. The Levere and Bartus study demonstrates that in brief (one second) presentation of stimulus, the initial information gets attended to more than the later information.

LIST OF REFERENCES

- Battig, K., Rosvold, H. E., and Mishkin, M. Comparison of the effects of frontal and caudate lesions on delayed response and alternation in monkeys. Journal of Comparative and Physiological Psychology, 1960, 53, 400-404.
- Cha, J. H., and King, J. E. The learning of patterned strings problems by squirrel monkeys. Animal Behavior, 1969, 17, 64-67.
- Cook, R. G. Retroactive interference in pigeon short-term memory by a reduction in ambient illumination. Journal of Experimental Psychology: Animal Behavior Processes, 1980, 6, 326-338.
- D'Amato, M. R. Delayed matching and short-term memory in monkeys. In G. H. Bower (ed.), The Psychology of Learning and Motivation: Advances in Research and Theory. Vol. 7. New York: Academic Press, 1973.
- _____ and O'Neill, W. Effect of delayed-interval illumination on matching behavior in the capuchin monkey. Journal of the Experimental Analysis of Behavior, 1971, 15, 327-333.
- Davis, R. T., and McDowell, A. A. Performance of monkeys on randomly presented string problems. Proceedings of South Dakota Academic Science, 1953, 32, 147-152.
- Devine, J. V., Jones, L. C., Neville, J. W., and Sakai, D. J. Sample duration and type of stimuli in delayed matching-to-sample in rhesus monkeys. Animal Learning and Behavior, 1977, 5, 57-62.
- Etkin, M. W. Light produced interference in a delayed matching task with capuchin monkeys. Learning and Motivation, 1972, 3, 313-324.
- Fantz, R. L., Ordy, J. M., and Udelf, M. S. Maturation of pattern vision in infants during the first six months. Journal of Comparative and Physiological Psychology, 1962, 55, 907-917.

- Finan, J. L. Delayed response with pre-delay re-inforcement in monkeys after removal of the frontal lobes. American Journal of Psychology, 1942, 55, 202-214.
- Finch, G. The solution of patterned string problems by chimpanzees. Journal of Comparative and Physiological Psychology, 1941, 32, 83-90.
- Fischer, G. J., and Kitchener, S. L. Comparative learning in young gorillas and orangutans. Journal of Genetic Psychology, 1965, 107, 337-348.
- Fletcher, H. J. The delayed response problem. In A. M. Schrier, H. F. Harlow, and F. Stollnitz (eds.), Behavior of Non-human Primates. Vol. 1. New York: Academic Press, 1965, Pp. 129-165.
- _____ and Davis, J. K. Evidence supporting an intratrial interpretation of delayed response performance of monkeys. Perceptual and Motor Skills, 1965, 21, 735-742.
- Grant, D. S., and Roberts, W. A. Sources of retroactive inhibition in pigeon short-term memory. Journal of Experimental Psychology: Animal Behavior Processes, 1976, 2, 1-16.
- Harlow, H. F. Recovery of pattern discrimination in monkeys following unilateral occipital lobotomy. Journal of Comparative Psychology, 1939, 27, 467-489.
- _____. Analysis of discrimination learning by monkeys. Journal of Experimental Psychology, 1950, 40, 26-39.
- _____. The development of learning in the rhesus monkey. American Scientist, 1959, 47, 459-479.
- _____ and Settlage, P. H. Comparative behavior of primates: VII. Capacity of monkeys to solve patterned string tests. Journal of Comparative and Physiological Psychology, 1934, 18, 423-435.
- _____. Effect of extirpation of frontal areas upon learning performance of monkeys. In J. F. Fulton, C. D. Aring, and S. B. Wortis (eds.), The Frontal Lobes. Vol. 27. Baltimore, MD: Williams and Wilkins, 1948, Pp. 446-459.
- Herman, L. M. Interference and auditory short-term memory in the bottle-nosed dolphin. Animal Learning and Behavior, 1975, 3, 43-48.

- Hobhouse, L. T. Mind in Evolution. London: Macmillan, 1901.
- Hunter, W. S. The delayed reaction in animals and children. Behavior Monograph, 1913, 2, No. 1.
- Jacobsen, C. F. Studies of cerebral function in primates. Comparative Psychology Monographs, 1936, 13, No. 63.
- _____ and Nissen, H. W. Studies of cerebral function in primates. Journal of Comparative Psychology, 1937, 23, 101-112.
- Jarrard, L. E., and Moise, S. L. Short-term memory in the monkey. In L. E. Jarrard (ed.), Cognitive Processes in Nonhuman Primates. New York: Academic Press, 1971.
- Kendrick, D. R. Effects of differential lighting on delayed-response in capuchin and squirrel monkeys. Unpublished doctoral dissertation, University of Arizona, 1980.
- King, J. E., and Clawson, J. R. Delayed-response by squirrel monkeys under various delay lighting conditions. Psychonomic Science, 1966, 6, 429-430.
- King, J. E., Flaningan, M. R., and Rees, W. W. Delayed-response with different delay conditions by squirrel monkeys and fox squirrels. Animal Behavior, 1968, 16, 271-275.
- King, J. E., and Fobes, J. L. Hypothesis analysis of sameness-difference learning set of capuchin monkeys. Learning and Motivation, 1975, 6, 101-113.
- _____. Application of sequential state theory to complex learning and sensory discrimination. In S. J. Suomi and L. A. Rosenblum (eds.), Advances in the Study of Primate Social Behavior. New York: Academic Press, in press.
- King, J. E., and Witt, E. D. The learning of patterned strings problems by rook squirrels. Psychonomic Science, 1966, 4, 319-320.
- Krechevsky, I. "Hypotheses" in rats. Psychological Review, 1932, 39, 516-533.
- Lentz, J. L., and King, J. E. Sources of errors by capuchin monkeys on delayed response. Animal Learning and Behavior, 1981, 2, 183-188.

- Levere, T. E., and Bartus, R. T. Stimulus information and primate discrimination learning: Preresponse utilization of stimulus information. Journal of Comparative and Physiological Psychology, 1971, 77, 200-205.
- _____. Stimulus information and primate discrimination learning: Utilization of preresponse stimulus information following acquisition. Journal of Comparative and Physiological Psychology, 1972, 79, 432-437.
- Levine, M. A model of hypothesis behavior in discrimination learning set. Psychological Review, 1959, 66, 353-366.
- _____. Hypothesis behavior. In A. M. Schrier, H. F. Harlow, and F. Stollnitz (eds.), Behavior of Nonhuman Primates. Vol. 1. New York: Academic Press, 1965, Pp. 97-127.
- _____. Hypothesis behavior by humans during discrimination learning. Journal of Experimental Psychology, 1966, 71, 331-338.
- _____. The size of the hypothesis set during discrimination learning. Psychological Review, 1967, 74, 428-430.
- _____, Miller, P., and Steinmeyer, C. H. The none-to-all theorem of human discrimination learning. Journal of Experimental Psychology, 1967, 73, 568-573.
- Luria, A. R. Higher Cortical Functions in Man. New York: Basic Books, 1964.
- Maki, W. S., Jr. Discrimination learning without short-term memory: Dissociation of memory processes in pigeons. Science, 1979, 204, 83-85.
- _____, Moe, J. C., and Bierly, C. M. Short-term memory for stimuli, responses, and reinforcers. Journal of Experimental Psychology: Animal Behavior Processes, 1977, 3, 156-177.
- Malmo, R. B. Interference factors in delayed response in monkeys after removal of frontal lobe. Journal of Neurophysiology, 1942, 5, 295-308.
- Mason, W. A., Blazek, N. C., and Harlow, H. F. Learning capacities of the infant rhesus monkeys. Journal of Comparative and Physiological Psychology, 1956, 49, 449-453.

- Mason, W. A., and Harlow, H. F. The effects of age and previous training on patterned string performance of rhesus monkeys. Journal of Comparative and Physiological Psychology, 1961, 54, 704-709.
- McDowell, A. A., and Brown, W. L. Intervening darkness and delayed response performance by rhesus monkeys. Journal of Genetic Psychology, 1960, 97, 59-65.
- Meyer, D. R., and Harlow, H. F. Effects of multiple variables on delayed response performance by monkeys. Journal of Genetic Psychology, 1952, 81, 53-61.
- Michels, K. M., Pustek, J. J., Jr., and Johnson, J. I., Jr. The solution of patterned strings problems by raccoons. Journal of Comparative and Physiological Psychology, 1961, 46, 439-441.
- Motiff, J. P., DeKock, A. R., and Davis, R. T. Concealment of stimuli during delay in the delayed-response problem. Perceptual and Motor Skills, 1969, 29, 788-790.
- Richardson, H. M. The growth of adaptive behavior in infants. Genetic Psychology Monographs, 1932, 12, 195-357.
- Richter, C. P., and Hines, M. Increased spontaneous activity produced in monkeys by brain lesions. Brain, 1938, 61, 1-16.
- Riesen, A. H., Greenberg, B., Granston, A. S., and Fantz, R. L. Solutions of patterned string problems by young gorillas. Journal of Comparative and Physiological Psychology, 1953, 46, 19-22.
- Riopelle, A. J. Performance of rhesus monkeys on spatial delayed response (indirect method). Journal of Comparative and Physiological Psychology, 1959, 52, 745-753.
- _____ and Churukian, G. A. The effect of varying the inter-trial interval in discrimination learning by normal and brain-operated monkeys. Journal of Comparative and Physiological Psychology, 1958, 51, 119-125.
- Roberts, W. A., and Grant, D. S. An analysis of light-induced retroactive inhibition in pigeon short-term memory. Journal of Experimental Psychology: Animal Behavior Processes, 1978, 4, 219-236.

- Rosvold, H. E., and Delgado, J. M. R. The effect on delayed-alternation test performance of stimulation or destroying electrically structures within the frontal lobes of the monkey's brain. Journal of Comparative and Physiological Psychology, 1956, 49, 365-372.
- Scanlon, J. L., and King, J. E. Learning and transposition of an extended sameness-difference concept by slow and fast learning capuchin monkeys. Animal Learning and Behavior, 1976, 4, 308-312.
- Settlage, P. H. The effect of occipital lesions on visually guided behavior. Journal of Comparative Psychology, 1939, 27, 93-131.
- Smith, H. J., King, J. E., and Newberry, P. Facilitation of discrimination learning set in squirrel monkeys by colored food stimuli. Bulletin of the Psychonomic Society, 1976, 1, 5-8.
- Stamm, J. S. Electrical stimulation of frontal cortex in monkeys during learning of an alternation task. Journal of Neurophysiology, 1961, 24, 414-426.
- _____, Stepien, I., and Levine, M. Locomotor delayed alternation by prefrontally ablated monkeys. Psychonomic Science, 1971, 22, 51-52.
- Tranberg, D. K., and Rilling, M. Delay-interval illumination changes interfere with pigeon short-term memory. Journal of the Experimental Analysis of Behavior, 1980, 33, 39-49.