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Error Patterning and Hypothesis Behavior of Children and Pigeons in Discrimination Learning

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ERROR PATTERNING AND HYPOTHESIS BEHAVIOR OF CHILDREN AND PIGEONS IN DISCRIMINATION LEARNING

by

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ABSTRACT

Error Patterning and Hypothesis Behavior of Children and Pigeons in Discrimination Learning

by

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Characteristic distributions of errors across fixed ratio schedules of reinforcement were studied for two types of discrimination paradigms. Two experiments studied error patterns as a function of hypothesis behavior in two species of animals, children and pigeons.

Three key zero-delay matching-to-sample and two key simultaneous discrimination were reinforced for both species of animals on fixed ratio schedules of reinforcement. Experiment 1 involved children on matching-to-sample and simultaneous discrimination, and Experiment 2 involved pigeons on matching-to-sample and simultaneous discrimination. Both species of subjects experienced experimental conditions in which shift or stay response hypotheses were selectively reinforced using a high speed digital computer.

Data protocols were scored into four exhaustive error classes; win-stay, lose-shift; win-shift, lose-stay; win-stay, lose-stay; and win-shift, lose-shift errors. These four error types were scored by frequency of

occurrence and response latency for the ordinal positions of the fixed ratio. Two types of error patterns were defined for individual subjects. A standard error pattern was defined as having 15% more first half ratio errors than last half ratio errors. A reversed error pattern was defined as having 15% more last half ratio errors than first half ratio errors.

Experimental results indicated that selective reinforcement of particular response hypotheses produced only small effects for either species of animal on matching-to-sample or simultaneous discrimination. Response latencies for matching-to-sample and simultaneous discrimination were divided into two classes. The first class included long latency responses occurring immediately after reinforcement for children and pigeons. The second class included shorter latencies in the succeeding ordinal positions of the ratio for children and pigeons.

A majority of standard error patterns were produced when the total errors were separated into specific error types for low accuracy subjects of both species. The standard error pattern was lost for total errors due to a very high frequency of win-shift, lose-shift errors which were not distributed in any characteristic pattern. Higher accuracy subjects of both species tended to show a majority of reversed error patterns or no patterning when total errors were separated into error types. These subjects had very low frequencies of win-shift, lose-shift errors. The high frequency of win-shift, lose-shift errors in both species of animals across discrimination paradigms could be due

to the complexity of the discrimination, a developmental age base for human subjects, or a 0-second intertrial interval.

(156 pages)

INTRODUCTION

Several studies have reported effects of cyclic schedules of reinforcement on matching-to-sample and simultaneous discrimination performance (Davidson & Osborne, 1974; Ferster, 1960; Mintz, Mourer, & Weinberg, 1966; Nevin, Cumming, & Berryman, 1963; Zeiler, 1968). It has been reported in these studies that errors are characteristically distributed between cyclically scheduled reinforcements. These error distributions have been named error patterns (Davidson & Osborne, 1974; Osborn & Burns, 1975) and different types of error patterns have been reported for fixed-ratio (FR) and fixed-interval (FI) schedules of reinforcement. It has been suggested by Osborne and Burns (1975) that these error patterns might be a function of selected response strategies and hypotheses exhibited by a subject.

The behavior of organisms is not due to chance in new problem situations. On the contrary, animals emit patterns of responses (Krechevsky, 1932) in new environmental situations. These patterns are systematic and are conceived of as behavioral attempts to solve new problems. They have been named hypothesis behavior (Krechevsky, 1932) and represent attempts by the organism to predict and control his environment systematically. The question of how hypothesis behavior is acquired and maintained is of considerable theoretical concern in an experimental analysis of discrimination performance.

Discrimination performance can be studied using a variety of discrimination procedures. In successive discrimination training, one stimulus either the negative stimulus (S-) or the positive stimulus (S+) is presented separately on each trial. Simultaneous discrimination training involves the presentation of both the S+ and S- on each trial. The simultaneous discrimination procedure allows a direct comparison of both the S+ and S- because they occur at the same time. The successive discrimination procedure does not allow such a time locked direct comparison. A third type of discrimination procedure called matching-to-sample involves a conditional discrimination. This stimulus discrimination paradigm utilizes a sample stimulus and comparison stimuli. For concreteness, on trial N the subject makes a response to the sample stimulus. On trial N + 1 the subject makes a response to a comparison stimulus. If the comparison stimulus correctly matches the sample stimulus, then the organism is reinforced. The generic label of a conditional discrimination is placed on the matching-to-sample procedure, because accuracy is determined by two or more aspects of the stimuli presented on successive trials.

The matching-to-sample procedure has had wide application in many types of psychological procedures and investigations. Weinstein (1941) has used matching-to-sample as a comparison procedure between species such as monkeys and children. It has also served as a partial base for a number of psychological tests of general intelligence (Stanford-Binet, 1964) and achievement tests (Peabody Individual Achievement Test, 1970).

The purpose of this study was to investigate error patterns and hypothesis behavior in matching-to-sample and simultaneous discrimination for children and pigeons by attempting to reinforce particular classes of hypotheses. It is a concern of this research to point out the relationships which exist between error patterns and hypothesis behavior and the independent variables which affect both.

REVIEW OF THE LITERATURE

Characteristic distributions of errors on cyclic schedules of reinforcement have been investigated by a number of researchers (Davidson & Osborne, 1974; Ferster, 1960; Mintz, Mourer, & Stein, 1968; Osborne & Burns, 1975) for a number of discrimination procedures. This distinct patterning of errors has been suspected by some researchers (Osborne & Burns, 1975) of being a function of response hypotheses held by subjects. The production of hypothesis behavior has been assumed by some investigators (Osborne & Burns, 1975; Sidman & Stoddard, 1967) to be reinforced "inadvertently" by experimental contingencies unknowingly programmed by the experimental contingencies that could possibly reinforce hypothesis behavior (Fellows, 1963; Gellerman, 1933; Moody & Gollin, 1973) such as the sequencing of the discriminative stimuli across conditioning trials.

In an effort to investigate the production of error patterns, this review will cover two basic factors thought to contribute to error pattern production, hypothesis behavior in discrimination learning and stimulus sequences in two-choice discrimination learning. This review will also cover the discrimination paradigms that are known to reliably show error patterns, that is matching to sample and simultaneous discrimination.

Hypothesis Behavior in Discrimination Learning

Lashley (1929) indicated that discrimination responses represented "attempted solutions" to solve the discrimination problem before the correct final response was made. This early interpretation of attempted solutions suggested to Krechevsky (1932) that the period prior to learning did not represent chance behavior, but a systematic attempt by an organism to solve a discrimination problem. The organism came to each new problem with a history of problem solving and an innate biological mechanism (Krechevsky, 1933) which led to systematic attempts to solve new problems.

Krechevsky (1932) used a double-alley discrimination box in a series of three experiments to investigate hypothesis behavior in rats. Experiment I incorporated two equally illuminated alleys one of which was blocked with a hurdle. The hurdle, which the rat had to climb over, served as the positive discriminative stimulus which indicated that food was at the end of the alley. The other alley which did not contain a hurdle contained no food. The absence of the hurdle served as the negative discriminative stimulus. All rats were run until they mastered the discrimination.

Krechevsky presented single subject data and used Rat # 20A as a typical example of an animal exhibiting hypothesis behavior in Experiment I. This subject tried a right-alley-only position habit which advanced from a chance level to peak well above chance and finally decline back to chance as the correct hurdle habit increased. Krechevsky reported that out of a total of 40 experimental animals, 36 displayed definite systematic attempts at a solution before the correct hurdle habit was selected.

Experiment II also involved a double-alley discrimination box with rats as subjects. Initially in this experiment a lighted alley led to food and served as the S+. A dark alley served as the S-. After the light alley discrimination was firmly established, a stimulus reversal condition was initiated. In the reversal condition, the S+ was the dark alley and the S- was the light alley. Krechevsky used subject Rat # 13 as a representative example, and showed that an incorrect right alley position habit was below chance during the light = S+ phase. But this right position habit advanced significantly above chance during the stimulus reversal phase until the correct dark alley discrimination was formed.

The last experiment, Experiment III, was done as a control to answer the possible criticism that the attempted solutions in Experiments I and II were mere blind habits reinforced by uncontrolled variables in the experimental alleys. In this experiment, each stimulus aspect of the double alley box was reinforced with food randomly 50% of the time. The four discriminative stimuli (left side, right side, dark alley, and light alley) never led to food more than at a chance level.

The results indicated that various hypotheses such as a right position habit or a dark alley habit would increase from a chance level and then return to a chance level. After one type of hypothesis was tried by a rat and abandoned, another type would be systematically tried. No hypothesis was ever maintained above a chance level for an extended period of time.

Krechevsky concluded that these attempted solutions represented an orderly and systematic manner in which an animal adjusted to his environment. In any new situation, the animal was not a confused victim of his environment in the sense that each response was a result of a specific momentarily-acting stimulus. The animal brought to each new environmental situation a whole history of experience. These past experiences led to systematic attempts to solve new discrimination problems. It was these systematic attempts that Krechevsky named "hypotheses." Krechevsky ascribed the following behavioral characteristics to the term: (1) hypothesis behavior is purposive (displaying an "if-then" character); (2) hypothesis behavior is systematic; (3) hypothesis behavior involves some degree of abstraction; and (4) hypothesis behavior does not depend entirely upon the immediate environment for its initiation and performance.

After the work of Lashley (1929) and Krechevsky (1932) a number of hypothesis models were developed. Each of the models (Bower & Trabasso, 1964; Levine, 1959; Restle, 1962) have assumed that all possible hypotheses are known to the subject at the beginning of the experiment. The learning task is to select the correct hypothesis from the known total hypothesis pool.

A slightly different approach to the explanation of discrimination learning was developed by Harlow (1949, 1950, and 1959). Harlow (1959) proposed that learning was a process of eliminating error tendencies from the animal's repertoire. These tendencies or "error factors" were defined as "reaction tendencies or interactions between or among reaction tendencies leading to ordered but inappropriate responses to a problem" (Harlow, 1959, p. 513).

Harlow was able to trace the course of several distinct classes of errors over successive trials in many types of learning set problems. He reported four basic types of errors (Harlow, 1959)-- (1) Stimulus perseveration: This involved a repeated choice of a stimulus object; (2) Differential cue error: Defined by Reese (1963) as "errors on the first trial on which a correct stimulus object changes position, related to errors on which the incorrect stimulus remains in the same position" (p. 133); (3) Response shift errors: Defined as the number of errors following a series of correct responses when the initial response was correct relative to the number of such errors when the initial response was incorrect; and (4) Position-preference errors: Defined as repeated responses to a spatial position.

The degree to which these types of errors were sensitive to experimental manipulation was the object of an experiment done by Schrier and Harlow (1956). The purpose of the experiment was to decrease or increase the frequency of three of the error types mentioned above, response-shift errors, differential cue errors, and position preference errors. Schrier and Harlow used a learning-set procedure with a Wisconsin General Test Apparatus and eight Java monkeys as subjects. Three amounts of reinforcement were used, either 1, 2, or 4, 2.2 gram food pellets in a series of

10-trial planometric discrimination problems. A total of 432 problems was presented to each subject.

The frequency of response-shift errors was found to be inversely related to the amount of incentive, but neither the differential-cue errors or the position-preference errors were found to be related in any systematic way to the amount of incentive. This experiment provided the earliest evidence that a form of hypothesis behavior could be systematically reinforced.

Levine and Schrier (Harlow, 1959) formulated a new interpretation of Harlow's error factor theory. Levine defined error factors as unique patterns of responses made to irrelevant aspects of the stimulus situation. Levine (1959) used this new interpretation as a basis for a mathematical model to describe hypothesis behavior in simultaneous discrimination and learning set procedures. The model was reformulated (Levine, 1966, 1967, and 1969) to account for hypothesis behavior in multidimensional, simultaneous discrimination problems using humans as subjects.

The most common multidimensional problems that Levine has used vary on four to eight dimensions. An example of a four-dimensional problem varies type of alphabetical letter, the size of the letter, the color of the letter, and a horizontal bar below or above the letter. For any one problem, one of these dimensions serves as the S+ while the other three serve as S-s. A four-dimensional problem has three blank trials in which the subject receives no information about the correctness of the dimension he is responding to, and one feedback trial in which he receives correctness information. In any problem, the response pattern across trials uniquely defines the four hypotheses associated with each stimulus dimension. For this model a hypothesis is a unique and specific pattern of response to a selected stimulus set (Levine, 1959, 1969).

The formal assumptions of the 1969 model are: (1) the basic assumption: a sample hypothesis determines the response of a subject; (2) the blank trials assumption: the subject responds to a single hypothesis across a series of blank trials; (3) the composition assumption: the hypothesis pool is finite and known to the experimenter; and (4) the oops-error assumption: on any blank trial the subject has a constant probability of choosing incorrectly relative to his sample hypothesis. The validity of each of the above assumptions has been established (Levine, 1969).

The data from four-dimensional problems falls into two classes, eight patterns conforming to stimulus specific hypotheses and eight patterns not conforming to stimulus specific hypotheses and thus random responding. On blank trials, hypothesis patterns appeared 92.4% of the time (Levine, 1969) confirming the blank trials assumption. Each set of blank trials permitted an inference of the current hypothesis being held by a subject and allowed a prediction of the next trial response. When predictions were made, they were correct 97.5% of the trials (Levine, 1966).

A theoretical improvement over Levine's (1969) model has been advanced by Gholson, Levine, and Philips (1972). In essence Gholson et al.

held that a subject is able to work with a variable number of hypotheses across blank trials. The selection or number of hypotheses that a subject works with follows a distinct plan called a "system." A system is defined as a specific sequence in which hypotheses are manifest across feedback trials. The sequences within a system can be categorized as focusing, hypothesis checking, dimension checking, and stimulus preferences.

When a subject uses focusing as a technique to solve a discrimination problem, he immediately eliminates all logically disconfirmed hypotheses on a negative feedback trial (Eimas, 1969). For example, if the stimulus chosen on a negative feedback trial was a large, white, and square stimulus all of these attributes are rejected and not sampled on the other trials. Dimension checking involves checking all dimensions systematically, one dimension at a time (Erickson, 1968). If the subject samples a stimulus from a dimension and it is a disconfirmed, on the next trial he will pick a new value of a dimension to test. In hypothesis checking, a subject picks a stimulus from a dimension such as black and if it is disconfirmed he will pick its complement, white, for a test on the next trial. If white is then disconfirmed, he will pick a new stimulus dimension to sample from. A stimulus preference technique results in a subject picking one stimulus and staying with it even though it is disconfirmed repeatedly.

The method which leads to a solution in the fewest number of trials is focusing; dimension checking is next in efficiency; hypothesis checking is less efficient; and stimulus preference is least efficient. Because stimulus preference will not lead to problem solution it is named a response "stereotype" by Gholson et al. Focusing, dimension checking, and hypothesis checking all eventually lead to problem solution and are called response "strategies."

The details of the Gholson et al. (1972) research are interesting, because this study is an excellent example of current hypothesis research with children. Two experiments were performed with groups of kindergarten, second grade, fourth grade, sixth grade, and college students. The discriminative stimuli used for both experiments varied along five dimensions. The stimuli were: type of alphabetical letter, color of letter, size of letter, bar above or below letter, and position of letter (left or right). All subjects were pretrained on the five-dimension problems and told to restrict their responses only to the presented dimensional stimuli. Each problem contained four blank trials and one feedback trial.

Experiment I compared second graders, fourth graders, sixth graders, and college students on six, 76-trial problems. There was a total of 16 feedback trials and 15 sets of four blank trials. The results indicated that all subjects showed hypothesis behavior on 90% of all blank trials. After a correct feedback trial, all subjects retained a confirmed hypothesis 95% of the time. But college students and school children differed on the number of disconfirmed hypotheses retained after a negative feedback trial. College students virtually never kept a disconfirmed hypothesis. School age children kept a disconfirmed hypothesis 10% of the time after a negative trial.

The purpose of Experiment II was to explore the usefulness of the hypothesis concept with very young children. Two groups of children were used, second graders and kindergarteners. The stimuli used in this experiment were the five dimensional stimuli used in Experiment I. In Experiment II, however, the feedback given to the subject was preprogrammed into six sequences. A total of nine experimental problems of 25 trials each was given to each subject.

The results indicated that second graders maintained consistent hypotheses over 80% of the blank trials. Kindergarteners maintained consistent hypotheses over 40% of the blank trials. Position preferences and position alternation accounted for 84% of the kindergarteners' inconsistent blank trial behavior. As in Experiment I, second graders maintained disconfirmed hypotheses 10% of the time. Kindergarteners' maintained disconfirmed hypotheses 45% of the time.

Gholson et al. (1972) found interesting differences in the types of hypotheses used by college students and school-aged children in the pooled data from Experiments I and II. College students used the two most efficient systems equally often that is, focusing and dimension checking. Second, fourth, and sixth graders used dimension checking most frequently with little focusing. Kindergarteners used position alternation which is a response stereotype with the greatest frequency.

Gholson and McConville (1974) in a recent study tried to improve the performance and efficiency of kindergarten children by appropriate pretraining.

The experimental design utilized a control group of 25 subjects and an experiment group of 25 subjects. The pretraining of both the experimental and control groups consisted of giving each subject 24 oddity problems which were six trials in length. Each problem contained three object stimuli two of which were identical and the solution was to pick the odd object. The experimental group received feedback (right or wrong) after every response while the control group was given no information feedback during pretraining.

The discrimination learning phase of the experiment consisted of 46, five-trial problems with information feedback delivered every fifth trial. The problems were the same as those used in Gholson et al. (1972).

The experimental outcome showed that the pretrained experimental group solved more discrimination problems than the control group. On blank trials, the experimental group displayed consistent hypotheses on 73.2% of the trials, while the control group displayed consistent hypotheses on only 55.9% of the trials. Of greatest interest, was the difference between response strategy and stereotypic behavior of the two groups. The experimental group used a dimension checking strategy predominantly 40% of the time. The control group used only stereotypic behavior with stimulus preference and position preference occurring on 58% of the trials.

The reliance on stereotypic responding by young children has been demonstrated by other investigators. Schusterman (1963) has shown that 3- and 10-year-old children and adult chimpanzees favor a relatively efficient win-stay, lose-shift strategy in learning set problems. While 5 year-old children consistently favor a position alternation stereotype. A strong position alternation stereotype was also found by Jeffery and Cohen (1965) with 4 1/2-year-old children in a two-choice situation with nondiscriminable stimuli and 100% reinforcement. Weir (1964) summarizing data from two- and three-choice tasks has suggested that a curvilinear relationship exists between age and single alternation stereotypes. Very young children, 3-4 years old, and adults use fewer alternation stereotypes while subjects from 7-10 years of age use a high proportion of simple alternation stereotypes.

Berman (1973) has recently replicated the predominance of single alternation stereotypes in young children. The subjects were 40 children 31-60 months old. The children were given 24, two-trial, object discrimination problems in a simplified Wisconsin General Test Apparatus. A single card was presented on Trial 1 which covered one of three wells. When the subject picked the card he was reinforced or not reinforced. On Trial 2, the original stimulus was presented with a new stimulus. If the subject picked the correct card which covered a well with a star in it, he was reinforced again. The problems were of four types: win-stay, lose-stay, win-shift, and lose-shift. On win-stay problems, the stimulus card picked on Trial 1 and reinforced would also be reinforced on Trial 2. On win-shift problems, the card picked on Trial 1 and reinforced would not be reinforced on Trial 2. On lose-stay problems, the card picked on Trial 1 and not reinforced was reinforced on Trial 2. On the lose-shift problems, the card picked on Trial 1 and not reinforced was not reinforced on Trial 2.

The difference between the shift and stay problems was striking. Subjects performed at chance levels on the stay problems, but solved 66% of the shift problems. This result indicated that confounding the solution of a discrimination problem with a response strategy bias in children facilitated solving that problem. Gerjuoy and Winters (1968) have implied a similar conclusion: "A coincidence between the highest strategy in a subject's hierarchy and the strategy needed to solve the problem will result in the fastest learning" (p. 52).

Thus the literature shows that it is possible to produce particular types of hypothesis behavior in humans and animals. Hypothesis production is related to amount of reinforcement, stimulus sequencing, and age of the subject.

<u>Matching-to-Sample Error Patterns with Cyclic Schedules of Reinforcement</u>

Distinct temporal distributions of errors between reinforcements are reported in the matching-to-sample literature. These error patterns are known to be produced by cyclic schedules of reinforcement such as fixed-ratio schedules (Davidson & Osborne, 1974). The prototypic error pattern produced by fixed-ratio schedules has the greatest frequency of errors occurring immediately after reinforcement and declining in frequency as the number of correct responses approaches the subsequent reinforcement. The error pattern associated with fixed-interval schedules has the greatest frequency of errors occurring in the second quarter of the interval with the error frequency declining progressively across the remaining two quarters of the interval (Ferster, 1960).

Ferster (1960) was one of the first investigators to use intermittent cyclic and noncyclic schedules or reinforcement with a matching-to-sample task. Ferster trained two pigeons to peck a center sample key which was one of two colors, red or white. After the sample key was pecked, the sample key went dark and two comparison side keys were illuminated (zero-delay matching-to-sample). One comparison key matched the previous sample key's color and the other comparison key did not match. A correct comparison response produced a brief magazine light flash, whereas an incorrect match turned off all chamber illumination briefly. Following either an error or a correct match the sample key was again illuminated and a new trial was started. The procedure utilized a correction procedure in that each non-matching response produced the same sample and comparison stimuli until the pigeon chose the correct comparison. The pigeons were exposed to continuous reinforcement (CRF), fixed ratio (FR), fixed interval (FI), and variable interval (VI) schedules for matching.

Ferster observed error patterns only for FI schedules. The percentage of errors was greatest in the second quarter of the interval and progressively decreased in succeeding quarters.

Nevin, Cumming, and Berryman (1963) also investigated the effects of FR schedules on the matching-to-sample performance of pigeons. This experiment used three colored keys in a discrete trial procedure. Trials were separated by an inter-trial interval (ITI) of 1 second if the match was correct and 25 seconds if the match was incorrect. The procedure required five observing responses to the center sample key which resulted in the illumination of the two side comparison keys. All three keys remained illuminated until the comparison keys had been pecked (simultaneous matching-to-sample). The procedure was noncorrectional and only correct responses advanced the ratio requirement. The birds were started on CRF and switched to FR values of 3, 6, and 10. Distinct error patterns developed. The greatest frequency of errors occurred immediately after reinforcement and decreased as the ordinal position of the ratio increased.

Mintz, Mourer, and Weinberg (1966) have systematically replicated the Nevin et al. (1963) findings. They used five pigeons in a zero-delay matching-to-sample procedure. The experimental conditions had the added feature of 10 vertical lights, nine of which were illuminated with successive steps of the ratio. For example, at the beginning of each trial the bottom light in the array was illuminated. Each correct match illuminated another light moving from the bottom of the array to the top. An FR 9 was used in the experiment so that at the end of the nine correct matches 10 lights were illuminated. All 10 lights remained illuminated while the reinforcement was delivered. The vertical array of lights acted as a probe to assess the extent that errors were under stimulus control of the position in the ratio.

The pigeons were run for 60 experimental sessions at which time it was evident that there was a distinct error pattern. Most errors occurred immediately after reinforcement when the first light was illuminated and fewest occurred after eight matches when nine lights were illuminated. The procedure was then changed and the eighth light came on immediately after reinforcement. The pigeons had now only to complete an FR 2 to obtain reinforcement. The error frequencies of these two ordinal positions resembled the error frequencies of positions eight and nine in the initial procedure. This result indicated that errors were under the partial control of the light array, but did not rule out the possibility that the number of errors was a function of time to reinforcement.

Mintz, Mourer, and Stein (1968) performed a similar experiment but used no light arrays as probes and evaluated the effects of two drugs, Librium and D-amphetamine, on matching-to-sample performance of pigeons. The procedure used an FR 9 with a zero-delay match-to-sample paradigm. The Librium dosages administered were 0.0, 0.5, 1.0, 2.0, and 4.0 mg/kg, and the D-amphetamine dosages were 0.0, 0.5, 1.0, and 2.0 mg/kg.

Overall error rates were not effected by either drug except for one subject whose error frequency increased as the dosage of D-amphetamine increased. Both Librium and D-amphetamine did not alter the basic FR error pattern. But under some dosages Librium and D-amphetamine increased the errors in the last ordinal position. The drug effect was one of a redistribution of errors and not a change in the overall error frequency.

The latency data from Mintz et al. (1968) suggested that there were two classes of errors in the matching-to-sample situation. The latencies of errors, which were measured as the time between the response to the sample key and the response to the comparison key, were distributed in bimodal fashion. Latencies of the first ordinal position were unusually long. But beyond this ordinal position in the ratio errors were produced by rapid match attempts. The effect of both drugs was to produce a general increase in response latencies.

Complex schedules of reinforcement have also been used to demonstrate error patterns with the matching-to-sample procedure. Boren and Gollub (1972) used three types of schedules: FI, chained FI, and FI with exteroceptive stimulus change correlated with time since last reinforcement (an added clock). The chained FI schedule had an added FR 3 response requirement at the beginning and end of the time interval. The FI (added clock) schedule utilized three colored lights to indicate time during the interval. The lights were the same as the conditioned stimuli for the chained schedule. The FI values varied from 48 seconds to 383 seconds. Latency data and frequency of errors during each 12th of the session were recorded for the pigeon subjects.

The results indicated that for all four subjects performance was most accurate at high rates of responding or very low rates of responding. A U-shaped function described response accuracy with accuracy being poorest at average rates of responding between the high and low rate extremes. The error patterns produced by the simple FI schedule replicated Ferster's (1960) findings. The highest frequency of errors occurred in the second to seventh 12th of the interval. The error patterns generated under the chained schedule were somewhat different than under the single FI schedule. Performance on this schedule was under the control of the chained stimuli, particularly the terminal stimulus. This stimulus increased the frequency of errors in the last part of the interval. The FI (added clock) schedule produced error patterns similar to those produced by the single FI schedule.

Davidson and Osborne (1974) investigated error patterns produced by children on a matching-to-sample procedure under a variety of schedules. They used FR, FI, variable ratio (VR) and VI schedules of reinforcement. Three types of matching-to-sample procedures were also used: simultaneous, zero-delay, and 2-second delay.

FR 3 to FR 10 and VR 3 to VR 6 were examined. Errors did not count toward the completion of the ratio. Reliable error patterns with most errors occurring immediately after reinforcement and fewer errors occurring in subsequent positions in the ratio occurred for the 2-second delay and zero-delay conditions on FR schedules for all the subjects. Simultaneous matching-to-sample using an FR schedule did not produce consistent error patterns. Nor did consistent error patterns develop when VR schedules were used with any of the matching-to-sample conditions. Of interest to error pattern production was the total accuracy of the subjects on FR schedules. Davidson and Osborne found that the error pattern effect was weakest for the most accurate subjects on the simultaneous matching-to-sample condition. The authors concluded that "a minimum number of errors would seem necessary before error patterns can be determined" (p. 34).

The FI and VI schedule values ranged from 12 seconds to 48 seconds. A clear pattern of errors developed for all children who experienced the zero-delay matching reinforcement. The error patterns were of the type found by Ferster (1960). The VI schedules of equal reinforcement density failed to produce reliable error patterns. The overall accuracy on the VI schedules was lower than that of the FI schedules.

Two important points concerning error patterns were made by the Davidson and Osborne (1974) study. First, error patterns were produced only by cyclic schedules of reinforcement such as FR and FI schedules. Variable schedules of reinforcement did not produce consistent error patterns. Second, a minimum number of errors was needed before error patterns were produced.

In summary, the reviewed matching-to-sample literature for children and animals shows that error patterns can be reliably produced. The characteristics of these patterns are dependent upon the type of reinforcement schedule either interval or ratio. The occurrence or nonoccurrence of error patterns are dependent upon a minimum number of errors occurring and the cyclic nature of the schedule of reinforcement. Variable schedules of reinforcement did not produce error patterns.

Simultaneous Discrimination Error Patterns with Cyclic Schedules of Reinforcement

A number of researchers have shown that the error patterning phenomenon is not limited to matching-to-sample. Nevin (1967), Zeiler (1968), and Osborne and Burns (1975) have produced error patterns with simultaneous discrimination procedures, and FR schedules of reinforcement in both pigeons and children. The error pattern has been the same general type as that produced with matching-to-sample, most errors occurring immediately after reinforcement and progressively declining in number over succeeding ordinal positions in the ratio.

Nevin (1967) conducted three experiments to assess the effects of reinforcement scheduling on simultaneous discrimination performance. He trained pigeons to peck two differentially illuminated keys. The brighter key served as the S+ while the darker key served as the S-. All trials were separated by a 6-second intertrial interval.

Experiment I was conducted to assess accuracy of responding as a function of reinforcement frequency. The schedules used were similar to a free-responding, variable interval schedule with a limited hold (Ferster & Skinner, 1957). Reinforcements were available on randomly selected trials without regard to previous reinforcement. For example, an RT 10 schedule of reinforcement resulted in a 3-second access to grain randomly scheduled every 10 trials on the average. An RT 1 schedule was analogous to a CRF schedule. The following schedule values were used in order of exposure for 1000 trials each: RT 5, RT 2, RT 10, RT 5, RT 25, RT 10, RT 50, extinction, RT 1, RT 5, and RT 50. The scheduling of reinforcements was designed to expose birds to descending frequencies of reinforcement with recovery values after the extinction of earlier values. A 2-second time limit was imposed on each trial. If the bird did not peck the S+ within 2 seconds or simply did not peck any key within 2 seconds, the keys were turned off and no reinforcement was collected.

The results indicated that there was no relation between frequency of reinforcement and accuracy of responding. Analysis of latencies for all of the schedule values revealed no differences between correct and incorrect responses. Latencies did tend to increase when reinforcement was less frequently programmed. There was no error patterning for any value of the RT schedules.

Experiment II was designed to investigate the effects of cyclic patterns of reinforcement on the accuracy of responding. Reinforcement was programmed on every Nth trial regardless of previous responding (FT). This schedule is similar to a fixed-interval schedule with a limited hold (Ferster & Skinner, 1957). The FR condition programmed reinforcement for every Nth correct response. Subjects were exposed to FT 5, FT 10, and FR 5 schedules in that order. Each schedule was in effect for 22 sessions of 250 trials each. Five sessions of CRF intervened between each of the different schedules. On the FT schedules, if the bird did not peck within 2 seconds or did not make a correct response within that time the keys went dark and any programmed reinforcements were lost.

The overall probability of responding increased as a function of the ordinal trials after reinforcement, but no distinct error patterns developed. The results of Experiment II were at variance with earlier matching-to-sample work (Nevin et al., 1963) with cyclic schedules of reinforcement. Experiment III was a replication of Experiment II but with a forced-choice procedure. The

S+ and S- remained on until the pigeon made a response. All subjects were exposed to an FR 5 schedule of reinforcement.

In every case, response accuracy was lowest immediately after reinforcement. Latency data indicated that latencies after reinforcement were extremely long. When the forced choice procedure was removed, the birds rarely pecked immediately after reinforcement and the error patterns disappeared.

Zeiler (1968) has also studied the relationship between cyclic schedules in simultaneous discrimination and error patterns. Pigeons were initially trained to peck three keys for a 4-second access to grain. The keys were three different colors with two of the colors serving as S-s and one color serving as the S+. The trials were not separated by an ITI. FR schedules were used and ranged in values from 1 to 250 responses. All key pecks to the S+ and S- advanced the ratio until the last response at which point only a response to the S+ produced reinforcement.

Zeiler reported that even though responses to the S- advanced the ratio, there were fewer responses to the S- than to the S+ stimuli. The relative frequency of the S+ responses was independent of the size of the FR. Error frequencies were very low but when errors occurred they usually came immediately after reinforcement and generally followed a response pause at high FR values. The clustering of errors immediately after reinforcement replicated Nevin's (1967) discrete-trial error patterning with a free operant task.

Osborne and Burns (1975) utilized human subjects to study error patterns on a simultaneous discrimination task with FR schedules. They used subjects ranging in age from 3 to 27 years old in a three-key simultaneous discrimination task. An FR schedule was used with the following response requirements: 1, 2, 4, 6, 8, 10, 12, 14, and 16. Colors served as the S+ and S-s and all three colors were displayed simultaneously on each trial. A 30-position stimulus sequence was employed in which the S+ remained in the same position for two consecutive trials on six occasions during the 30-trial sequence. No ITI separated the stimulus trials. As in Zeiler's (1968) study, all responses to the S+ and S-s counted towards the ratio requirement until the last response. The last response in each ratio had to be to the S+ to be reinforced.

The data analysis in the Osborne and Burns experiment was by ordinal position of the ratio and by the type of error in the ratio. An E_1 error was defined as responding to a position on which the S+ had been programmed on the prior ratio. An E_2 error was defined as "responding to one of the three stimulus locations that was neither the present location of the S+ nor the location of the S+ during the preceding ratio" (p. 10).

All subjects except one showed reliable FR error patterns with more errors in the first half than in the second half of the ratio. Errors in the first half of the ratio tended to be of the E_1 type. The one subject who did not show the general FR error pattern had more errors in the second half of the ratios and they were of the E_2 type. Midway through the experiment this subject shifted his error pattern from more errors in the second half to more errors in the first half of the ratio. Concomitantly with this shift was a shift in error types from a majority of E_2 errors to a majority of E_1 errors. This finding suggested that error patterns were a function of response strategies held by a subject, because distinctly different error patterns were associated with the two different types of errors.

In summary, the child and animal literature for simultaneous-discrimination experiments shows reliable error patterning for FR schedules of reinforcement. The error patterns for simultaneous discrimination are similar to those found in matching-to-sample experiments using FR schedules of reinforcement. Two important findings affecting error pattern production stand out in the simultaneous discrimination literature. First, error patterns have been shown to be a function of subject hypothesis behavior. Second, subject hypothesis behavior might be inadvertently reinforced by experimental conditions such as stimulus sequencing across trials.

Stimulus Sequences in Two-Choice Discrimination Learning

In two-choice discrimination problems, where subjects are required to make right and left choices the discriminative stimuli have been programmed randomly prior to the experiment. Generally they contain equal numbers of right and left presentations of the S+ and S-. Gellermann (1933) indicated that it was commonly assumed that orders of randomly alternating stimuli allowed only a 50% chance of responses to be correct but that this assumption was unwarranted. Response strategies such as position alternations could produce response accuracy as high as 70%.

Gellermann (1933) produced 44 stimulus sequences which were 10 trials in length to reduce the occurrence of simple alternation accuracy from 70% to only 50%. The stimulus sequences had to meet the following requirements:

1. Each series contained five right and five left stimulus presentations;

2. No series could have more than three right or left stimuli in succession;

3. At least two rights and two lefts appeared in both the first and last half of each stimulus series;

4. Each series contained only five reversals of stimuli from the right position to the left position; and

5. Each series offered a score of 50% correct to simple alternations or double alternations of a response.

The first three criteria were designed to produce a "well balanced" series in which position preferences were not reinforced. The fourth criterion was intended to reduce differential cues of frequently alternating stimuli. The fifth criterion was used to minimize the opportunity of making more than 50% correct responses through the use of an alternation strategy.

An interesting application of Gellermann's (1933) sequences of stimuli was done by Hively (1962) using a simultaneous matching-to-sample procedure with children. Hively ran a series of nine experiments which utilized stimuli that differed in shape, color, and size. All sequencing of the matching stimuli was arranged in sequences suggested by Gellermann (1933).

Hively reported that the most common errors were alternation and preservation errors. A number of interesting conclusions was made by Hively. First, as the complexity of the discrimination problem increased (adding more types of stimuli) the less likely a subject was to observe the relevant stimuli. Thus the number of errors increased and the more likely "incorrect hypotheses" would inadvertently be reinforced. Second, as the length of the stimulus sequence increased the probability of reinforcing error types increased producing higher rates of errors in longer problems. Third, when the response requirement was easy such as pushing a key the response cost for making errors was minimal. Thus when a subject was responding to a stimulus which had a 50% correlation with reinforcement such as position alternation or perseveration, the subject was working on a variable-ratio schedule with a mean of two. It is important to note that even though Hively (1962) used the suggested Gellermann (1933) sequences, the most common errors were of the alternation and perseveration types.

Fellows (1967) has suggested that even the Gellermann series could reinforce response strategies at a greater than chance level. In fact Gellermann Series 7, 13, 32, and 38 would reinforce a double alternation strategy at a 90% level. Sequences with the following characteristics were suggested by Fellows: (1) insure a chance level of performance to any of the four position hypotheses (position perseveration, position alternation, win-stay, lose-shift and win-shift, lose-stay); (2) to minimize the reinforcing effects of responding to these hypotheses.

Performance scores for the four position hypotheses were calculated using Hull's (1943) Postulate 4. Postulate 4 states that increments from successive reinforcements summate to yield a combined habit strength. For example, three reinforcements delivered to the left side in succession would yield the following performance score: left (1) + left (2) + left (3) = 6 for the left side performance score. Fellows derived 24, 12-trial sequences which differed from the Gellermann sequences in that position hypotheses were reinforced on a 50% chance basis.

Moody and Gollin (1973) investigated the properites of both the Fellows (1967) and Gellermann (1933) sequences by using computer simulation in a hypothetical simultaneous discrimination task. Five strategies: position preference; single alternation; double alternation; win-shift, lose-stay; and win-stay, lose-shift were run on the Gellermann and Fellows' sequences. A goodness-of-fit analysis was performed between response strategy and the suggested placing of the S+ according to each sequence.

Both the Fellows and Gellermann sequences were accurate in holding the position preference strategy at a 50% chance level. The Fellows sequence was also accurate at holding the single alternation strategy at a 50% chance level. The Gellermann sequences did not hold the single alternation strategy at a chance level. For the other three strategies tested, both kinds of sequences failed, although the Fellows sequences produced values closer to chance than the Gellermann sequences.

For long runs of sequences or if the subject changed strategies during the experiment, both types of sequences departed from chance reinforcement of response strategies. An example of a multiple strategy, would be double alternations between positions in a two-choice discrimination condition.

Four alternative controls are suggested by Moody and Gollin to evaluate two-choice discrimination learning performance and infer learning: first, a trial-by-trial analysis of response protocols to provide clues as to how the subject approached the discrimination problem; second, use of a transfer task to determine what the subject was responding to during discrimination; third, a pretest procedure to evaluate the subject's response bias and then to pick sequences which hinder or faciliate this bias; and fourth, on-line computer control to allow trial-by-trial monitoring and S+ placement during the experiment. According to Moody and Gollin, on-line computer control offers the greatest promise for response strategy control in discrimination learning. To date, this procedure has not been systematically tried.

Jenkins (1965) has pointed out the importance of antecedent consequences in successive discrimination learning for pigeons. Responsiveness is increased by an antecedent positive trial and decreased by an antecedent negative trial. Sequencing effects produce confounding when reinforced-nonreinforced antecedents are correlated with the discriminative stimuli.

In summary, a number of the studies reviewed have shown the importance of stimulus sequencing on hypothesis behavior. A number of techniques have been suggested to control inadvertent reinforcement of different types of hypothesis behavior. The technique which shows the most promise is the on-line computer control of stimulus presentations and monitoring of the subject's responding.

Statement of the Problem

The studies which have investigated error patterns with FR schedules in matching-to-sample and simultaneous discriminations have reported essentially the same findings, that is the greatest number of errors immediately after reinforcement and the fewest number of errors immediately before reinforcement (Davidson & Osborne, 1974; Mintz et al., 1968; Nevin et al., 1963; & Osborne & Burns, 1975). The exact factors which give rise to error patterns are not yet explicitly clear. Davidson and Osborne (1974) have indicated that cyclic schedules or reinforcement and a minimum number of errors are necessary, and Nevin (1967) has shown that a forced choice procedure is an important factor. Sidman and Stoddard (1967) have suggested that an experimenter might inadvertently include "hidden" sources of reinforcement in an experimental program which selectively alter the outcomes of some conditioning experiments. Osborne and Burns (1975) have indicated that one such source of hidden reinforcement in simultaneous discrimination experiments might be the sequencing of stimuli. Certain sequences of stimuli might inadvertently reinforce (Fellows, 1967; Moody & Gollin, 1973) hypothesis behavior in subjects. This selective reinforcement of hypothesis behavior might in turn place errors in characteristic patterns in cyclic schedules. An attempt to condition error patterns by the selective placement of the S+ across trials has not been systematically tried for matching-to-sample and simultaneous discrimination using FR schedules of reinforcement.

This research was designed to make explicit possible "hidden" sources of reinforcement in simultaneous discrimination and matching-to-sample for FR schedules of reinforcement. It was also the intent of the present research to use a hypothesis analysis of error patterns to determine the composition of these error patterns. The independent variable to be manipulated was the stimulus sequence presented to the subject. The dependent variables were error patterns, response latencies, and error types (win-stay, lose-shift; win-shift, lose-stay; win-stay, lose-stay; and win-shift, lose-shift errors) across FR schedules for zero-delay matching to sample and simultaneous discrimination.

A second feature of the present research is that it involved two different types of organisms as experimental subjects. Children, primates, and pigeons have been widely used as subjects in discrimination research (Blough, 1959; D'Amato & O'Neil, 1971; Ferster, 1960; Osborne & Burns, 1975), but rarely have they been used in the same study (e.g., Weinstein, 1941). Between study comparisons to evaluate species differences have always been confounded by important procedural differences. The present research is a comparative study in which the experimental conditions were held constant for both children and pigeons allowing a cross-species comparison of error types and patterns.

Summary

Thus the present research:

1. Manipulated stimulus sequences in an effort to produce types of errors and error patterns occurring across trials of FR schedules for zero-delay matching-to-sample and simultaneous discrimination.

2. Compared error production for two types of discrimination procedures, matching-to-sample and simultaneous discrimination.

3. Compared error production in two species, children, and pigeons.

4. Employed an analysis of hypothesis behavior to obtain a fine-grain analysis of error production and patterns.

METHOD

Experiment 1

Subjects

Four girls 4 (S2, S3, S4, S6) years of age and two boys 6 (S5) and 10 (S1) years of age served as subjects. All of the children were residents of Logan, Utah, and were solicited by a circular distributed on Utah State University's campus.

Apparatus

Room 406D of the Child Laboratory at Utah State University was used as the conditioning room. This room measures 8 ft. x 6 ft. and was dimly lit by a night light. The conditioning room contained a child-sized chair and table upon which the metal experimental console was placed. The console contained three stimulus light displays (I. E. E. Series 360) upon which three colors were projected (green, blue, and red). The three light displays were arranged in a horizontal line and were separated from each other by a distance of 4. 5 inches. Three and one-half inches below each light display was located a steel response lever. Depression of any of the three levers through a distance of 1. 5 inches activated a microswitch. The average force requirement to activate the microswitch was 270 grams. The console also contained two rows of vertical pilot lights and two digital counters. The digital counters were inoperative and taped over during the study. The pilot lights were arranged in two vertical rows; one of five to the left of the I. E. E. light displays and a second row of two to the right of the I. E. E. light displays.

Mexican 5-centavo pieces served as tokens and were presented to the subjects as reinforcers for responding. Centavos were dispensed by a National Cash Register coin changer located to the right of the console. A PDP 8-L digital computer scheduled all experimental events and recorded the subject's data for each experimental session.

Procedure

Each subject was introduced to the experimental situation with an explanation that they were to push levers to receive centavos. The centavos could be exchanged at the end of the experimental session for a variety of back-up reinforcers such as small toys and candy. A subject could earn 30 centavos per day and was able to exchange them for reinforcers at a rate of 0.5 cent per centavo.

On each conditioning day, the subjects were led from a waiting room and brought to the conditioning room. The subjects were seated before the console and heard the following instructions from the experimenter each day:

> "Please, sit in the chair facing the console. Look at the lights when they come on, and remember to use only one hand at a time to press the levers. I will come and get you and count your money when the session is over."

After the instruction the experimenter left the conditioning room and closed the door. A white noise masking sound played over a speaker in the conditioning room was then turned on. A Sony tape recorder played the white noise for the duration of the session at approximately 75 db(A). After switching the masking noise on, the experimenter started the experimental session.

When the session was over, the experimenter initiated a data printout program by the PDP 8-L computer. The program printed all of the subject's data on a teletype while simultaneously punching the data on paper tape. The paper tapes were later read into a Burroughs 6700 computer over teletype-telephone couplers to be machined scored.

Two discrimination procedures were used, a matching-to-sample procedure and a simultaneous-discrimination procedure. Three children (Subject 1, Subject 2, and Subject 3) were randomly assigned to the matching-to-sample procedure. The three other children (Subject 4, Subject 5, and Subject 6) were randomly assigned to the simultaneous-discrimination procedure.

The matching-to-sample condition utilized the three horizontal I. E. E. light displays located on the experimental console. The center light always served as the sample stimulus and the left and right displays served as the comparison stimuli. Colors of the sample stimuli varied randomly for each trial. A total of three colors--red, green, and blue--was used. A subject would depress the lever under the sample stimulus light at which time the comparison stimuli would be illuminated. A response to either comparison stimulus completed a trial. The comparison stimuli would then immediately go off and a new sample stimulus would be illuminated starting a new trial. If the choice of the comparison stimuli had been a correct match, the two top red pilot lights to the right and left of the comparison stimuli would flash for approximately 1/4 of a second. If the match was incorrect, no pilot lights flashed and a new trial was started.

The initial matching-to-sample employed a simultaneous matching-to-sample procedure (having the sample stimulus on when the comparison stimuli were on) utilizing a CRF schedule of reinforcement to facilitate acquisition. Subjects remained on the simultaneous-matching-to-sample condition with the CRF until they were making more than 50% correct responses each session. After the subjects met this criterion, they were switched to a zero-delay-matching-to-sample condition with larger FR schedule response requirements. Subject 1, Subject 2, and Subject 3 were placed on an FR 6 schedule after the CRF condition. After six experimental sessions, Subject 3 was not responding above chance at which time she was switched to an FR 3 schedule for the duration of the experiment.

In the simultaneous-discrimination condition the right and left light displays were used leaving the center light display inoperative. One color either blue, red, or green, was randomly selected as the S+ and remained the S+ for each subject for the entire experiment. The remaining two colors became the S-s. On each trial, one S- and the S+ was presented to the subject. The subject responded by depressing a lever either under the S+ light or the S- light. If the choice had been to the S+ the two red pilot lights flashed for approximately 1/4 of a second. If the choice had been to the S-, no pilot lights flashed. Immediately after a light choice had been made and the pilot lights had flashed or not flashed, a new trial was initiated with the same S+ but a new S-.

Simultaneous-discrimination conditioning sessions employed a CRF schedule until the subject was responding with more than 50% correct responses for each session. After the CRF condition subjects, Subject 4, Subject 5, and Subject 6 were switched to an FR 6 schedule. Subject 6 was on the FR 6 schedule for nine experimental sessions and was then switched to an FR 9 so that she would produce more errors.

For both the matching-to-sample condition and the simultaneous discrimination condition, errors did not count towards the ratio requirement. When errors were made, no pilot lights flashed and no tokens were ever dispensed. After each error a totally new trial was presented to the subject, thus no correction procedure was used. After the ratio requirement was fulfilled, a centavo was dispensed and a new trial started immediately. For each experimental session there was a total of 30 centavo reinforced responses. The total number of responses made during a session was dependent upon the ratio size and the number of errors made per session.

The main independent variable for both the matching-to-sample condition and the simultaneous-discrimination condition was the sequencing of the S+ with respect to position over session trials. The sequencing of the S+ over trials was of two general types, an "internal" FR sequencing and an "external" FR sequencing (Figure 1). The internal FR sequencing involved the placement of the S+ with respect to position for all the ratio trials except the last ordinal trial in the ratio to be reinforced. For the last ordinal trial in the ratio, the S+ stayed in the same position for two consecutive trials 50% of the time and shifted positions 50% of the time for all 30 (centavo) reinforced responses.

The external FR sequencing involved placement of the S+ with respect to position for the last reinforced ordinal trial in the ratio. For all the ratio trials leading up to the last ordinal trial but not including the last ordinal trial the S+ remained in the same position for two consecutive trials 50% of the time and shifted position 50% of the time.

Experimental condition A served as a baseline with the S+ remaining in the same position for two consecutive trials 50% of the time for both the external and internal FR trials. Conditions B, C, D, and E were of the external FR type in which S+ sequencing was manipulated for the last ordinal trial of the ratio. Condition B allowed the S+ to remain in the same position for two consecutive trials 67% of the time and shift 33% of the time. Condition C allowed the S+ to remain in the same position for two consecutive trials 33% of the time and shift 67% of the time. Condition D allowed the S+ to remain in the same position for two consecutive trials 90% of the time and shift 10% of the time. Condition E allowed the S+ to remain in the same position for two consecutive trials 10% of the time and shift 90% of the time. Conditions F and G were of the internal FR type in which the S+ position sequencing leading up to the last ordinal trial was manipulated. Condition F allowed the S+ to remain in the same position for two consecutive trials 90% of the time and shift 10% of the time. Condition G allowed the S+ to remain in the same position for two consecutive trials 10% of the time and shift 90% of the time. Figure 1 outlines each of the experimental conditions.

The S+ stay percentages for all the experimental conditions were based on a 30 sequence stimulus table. The stimulus table contained the colors of the stimuli to be presented and their position on the keys. For each trial, a stimulus and its position was selected from the stimulus table and presented to the subject. During an experimental session, a subject would be recycled through the 30 sequence stimulus table a variable number of times depending upon the number of errors made and the size of the FR requirement. The S+ stay percentage for the last ordinal trial of the ratio was determined by a 30 sequence reinforcement table. This table furnished the computer with information about which position was to be reinforced. The computer would select a stimulus from the stimulus table and a reinforcement side from the reinforcement table. With the information from both tables, the computer would then determine on which side the S+ would appear. For example, when a reinforcement was assigned to the right side, it stayed there until it was collected no matter how many errors were made to the other side. The stimuli on each attempt to collect a reinforcer would change, but not the position the reinforcement was assigned to. The exact color of the S+ was thus independent of the reinforcement sequence.

Five separate tapes were generated for each stimulus and reinforcement table for each experimental condition. All stays and shifts of the S+

for each stimulus and reinforcement table were programmed using a random number table. Each reinforcement table programmed half of the reinforcements to the left side and half to the right side. Each matching-to-sample stimulus table had equal numbers of stimulus colors serving as S-s and S+s in a 30 sequence table. The simultaneous discrimination tables had one color that served as the S+ and two colors which served as S-s equally often.

For each experimental condition, each subject had one of the five stimulus and reinforcement tables randomly assigned each day. A subject had to experience all five stimulus and reinforcement tables before that table could be assigned a second time.

Each subject started condition A as a baseline condition. Table 1 contains the experimental conditions as they were experienced by the subject, the number of sessions spent in that condition, and the FR value serving that condition. Each subject spent at least 5 days in each experimental condition. The criterion for shifting from one experimental condition to the next was that the subject's responding in the last experimental session was within $\pm$ 5% of the mean number of responses during the last 3 days of responding. Also there could not be a continuous trend over the last 3 days of responding. When these criteria were met, the last 3 days of responding in an experimental condition was used for data analysis.

Experiment 2

Subjects

Four pigeons acquired from the Green Canyon Ecology Compound and the Utah State Animal Laboratory served as subjects. All of the pigeons were maintained at 85% of their free-feeding weights. None of the birds had been used in prior conditioning experiments.

Apparatus

A Coleman 80-quart cooler with inside dimensions of 17 in. x 14 in. x 13 in. served as the conditioning chamber. The chamber was vented by an exhaust fan which also served to mask exterior noises. The bird's intelligence panel contained three response keys which measured 3/4 inches in diameter and were separated from each other in a horizontal line by a distance of 2 1/2 inches. A force requirement of 12 grams was required to activate a microswitch mounted behind each key. Behind each key was mounted a light projector (I. E. E. 360) which could project four kinds of lights on the keys (white, blue, red, and green). Located 4 inches below the center response key was a 1 3/4 in. x 2 1/2 in. feeder opening which contained a feeder tray and white feeder light. The birds were maintained on Purina Pigeon Chow in their home cages, and it also served as the feeder mixture in the conditioning chamber.

Procedure

Each bird was initially magazined trained in the chamber with no key lights on. When the birds were readily eating from the feeder, the center key light was illuminated with a white light and the birds were shaped to peck this key for 25 reinforcements of food. Commencing the next session, the center key was turned off and the right key was illuminated with a white light. The birds were shaped to peck this key and received 25 reinforcements. In the last shaping session, the left key alone was illuminated with white light and the birds received 25 reinforcements for pecking this key. Reinforcements for the shaping sessions and experimental sessions were 4-second presentations of the food hopper and hopper light.

Two birds, Subject 7 and Subject 8, were randomly assigned to the simultaneous discrimination condition, and two birds, Subject 9 and Subject 10, were assigned to the matching-to-sample condition. The experimental procedures and criteria for condition changes were exactly the same as for Experiment 1. The only difference between Experiment 1 and Experiment 2 was the nature of the subjects, the reinforcers used, and the pilot feedback lights. The feedback light for a correct response in Experiment 2 was a 1/4 second flash of the white hopper light. The stimulus tables and reinforcement tables used in Experiment 1 were also used in Experiment 2. Data collection, scheduling experimental events, and data analysis were done with a PDP 8-L computer in the same manner as Experiment 1.

All the birds began experimental condition A as a baseline condition. Table 1 outlines the sequence of conditions, the number of sessions in each condition, and the FR value serving that condition. Each bird experienced at least 5 days in each experimental condition. The criteria for changing from one condition to the next were the same as Experiment 1.

Table 1

The Experimental Conditions, Sessions, and FR Values

Experienced by Each Subject

Subjects	Condition	Sessions	FR Values
Child MTS			
S1	A	16	FR6
	B	6	FR6
	C	10	FR6
	D	6	FR6
	F	7	FR6
S2	A	30	FR6
	G	6	FR6
	F	6	FR6
	E	8	FR6
S3	A	13	FR3
	C	9	FR3
	B	10	FR3
	D	8	FR3
	F	6	FR3
	G	19	FR3
Child SD			
S4	A	13	FR6
	C	29	FR6
	G	21	FR6
	F	7	FR6
S5	A	18	FR6
	C	7	FR6
	D	9	FR6
	F	6	FR6
	G	8	FR6
S6	A	21	FR9
	B	10	FR9
	C	6	FR9
	D	9	FR9
	G	8	FR9
	F	8	FR9
	E	6	FR9

Table 1. Continued

Subjects	Condition	Sessions	FR Values
Pigeon MTS			
S7	A	17	FR6
	D	5	FR6
	F	6	FR6
S8	A	21	FR6
	E	5	FR6
	G	9	FR6
Pigeon SD			
S9	A	11	FR6
	G	7	FR6
	E	7	FR6
	F	6	FR6
	D	8	FR6
S10	A	13	FR6
	F	6	FR6
	D	5	FR6
	G	7	FR6

	INTERNAL FR (Responses within the ratio)		EXTERNAL FR (Reinforced responses)
	I------------------------N	- 1,	I---------------------N
	50% S+ STAY		50% S+ STAY
Condition A	I------------------------N	- 1,	I---------------------N
	50% S+ STAY		67% S+ STAY
Condition B	I------------------------N	- 1,	I---------------------N
	50% S+ STAY		33% S+ STAY
Condition C	I------------------------N	- 1,	I---------------------N
	50% S+ STAY		90% S+ STAY
Condition D	I------------------------N	- 1,	I---------------------N
	50% S+ STAY		10% S+ STAY
Condition E	I------------------------N	- 1,	I---------------------N
	90% S+ STAY		50% S+ STAY
Condition F	I------------------------N	- 1,	I---------------------N
	10% S+ STAY		50% S+ STAY
Condition G	I------------------------N	- 1,	I---------------------N

Figure 1. Experimental conditions as represented by the S+ sequencing across the FR.

RESULTS

All errors were computer scored into specific classes and by the ordinal position of the FR. This was accomplished by a trial-by-trial search of the data protocols by a Burroughs 6700 computer. Errors were divided into classes by a three-trial response definition. A three-trial response definition required two trials aside from the trial being scored to produce a unique error classification. For example, win-stay, lose-shift errors were defined as a response (N) made to the same position that the last correct response was made to, but shifting to the opposite position on the following response trial (N + 1). Win-shift, lose-stay errors were defined as a response made to the opposite position than the last correct response, with the following response in the same position. Win-shift, lose-shift errors were defined as a response made to the opposite position than the last correct response with a shifting of position on the following response. This type of error can be viewed as a form of single alternation in a two-choice situation. Win-stay, lose-stay errors were defined as a response made to the same position as the last correct response with the following response in the same position. This type of error can be viewed as a position preference error in a two-choice situation.

A two-trial response definition of errors was also reported. To achieve a two-trial error definition, a combination was made of two, three-trial error classes. For example, a win-stay error class was formed by combining the win-stay, lose-shift errors and the win-stay, lose-stay errors as originally scored by the computer. In a similar way, win-shift errors were formed by combining win-shift, lose-stay and win-shift, lose-shift errors; lose-stay errors were errors formed by combining win-shift, lose-stay and win-stay, lose-stay errors; and lose-shift errors were formed by combining win-stay, lose-shift and win-shift, lose-shift errors.

Error patterns as defined by ordinal position of the FR were also reported. Error patterns have been generally defined across all the ordinal positions of the ratio (Davidson & Osborne, 1974). But due to a great deal of response variability, first-half ratio errors and last-half ratio errors were combined into two separate error classes. A standard error pattern was then defined as having 15% or more errors in the first-half of the ratio than in the last half of the ratio for individual subjects. A reversed error pattern was defined as having 15% or more errors in the last half of the ratio than in the first half of the ratio for individual subjects. The data and text discussing the data for standard and reversed error patterns are included in Appendix C.

Mean response latencies were also reported for each experimental group for correct and error responses across ordinal positions of the ratio. The means were obtained by dividing the total response times by the total number of responses for all subjects in each experimental group. Two types of latencies, a sample latency and a comparison latency, were obtained for the matching-to-sample groups. The sample latencies were defined as the total time elapsed between the illumination of the sample light and the first sample response. The comparison latencies were defined as the total time elapsed between the illumination of the comparison lights and the first comparison response. Only one type of latency was reported for the simultaneous-discrimination groups. This latency was defined as the total time elapsed between the illumination of the two choice lights and the first choice response.

The .05 region was adopted for all statistical comparisons.

Error Patterns for Pooled Data

Table 2 presents the results of an error-pattern analysis performed on the pooled data for all the children who matched to sample. In this analysis the total number of errors for all subjects in each experimental group was divided into first and last half ratio errors. Of the total errors 54% were located in the first half of the FR and 46% of the total errors in the last half of the FR. The difference between these two percentages was significant as determined by a normal approximation to the binominal test ($z = 3.41$). An error analysis that separated errors into types indicated that for win-stay, lose-shift errors 63% of these were located in the first half of the FR and 37% in the last half of the FR when the two halves were compared ($z = 6.09$). A similar result was found for win-shift, lose-stay errors in which 58% of these errors occurred in the first half and 42% in the last half of the ratio ($z = 2.65$). However, this same result was not found for win-stay, lose-stay errors or win-shift, lose-shift errors. Both of these errors were not

Table 2

Error Frequencies and Percentages by Halves of the Fixed Ratio for

Pooled Data for Each Experimental Group

	Total		Win-Stay Lose-Shift		Win-Shift Lose-Stay		Win-Stay Lose-Stay		Win-Shift Lose-Shift	
	Matching-to-Sample Child Subjects									
First Half	1166*	54	339*	63	167*	58	107	45	553	50
Second Half	1006	46	197	37	121	42	129	55	559	50
	Simultaneous-Discrimination Child Subjects									
First Half	1871*	53	608*	54	127*	57	117	52	1019	51
Second Half	1674	47	516	46	95	43	108	48	955	49
	Matching-to-Sample Pigeon Subjects									
First Half	1284*	52	415*	57	208*	70	189*	74	471*	40
Second Half	1185	48	331	43	88	30	65	26	701	60
	Simultaneous Discrimination Pigeon Subjects									
First Half	101*	35	30*	25	11*	85	56*	38	4	80
Second Half	186	65	90	75	2	15	93	62	1	20

*$p < .05$

significantly distributed into the first or last half of the ratio; win-shift, lose-shift errors were the most frequent type.

An error-pattern analysis from pooled data for children in the simultaneous discrimination condition is also presented in Table 2. For total errors, a reliably larger percentage (53%) of the errors occurred in the first half of the ratio than in the last half of the ratio (47%), (z = 3.29). An analysis of the total errors into specific error types showed that this error pattern was evident in win-stay, lose-shift errors and win-shift, lose-stay. The win-stay, lose shift errors were located 54% in the first half of the ratio and 46% in the last half of the ratio (z = 2.71); the win-shift, lose-stay errors were located 57% in the first half of the ratio and 43% in the last half of the ratio (z = 2.08). Win-shift, lose-shift errors were the most frequent type of error but the percentages of first (51%) and last half errors (49%) were not reliably different (z = 1.41).

The pooled data for pigeons in the matching-to-sample is also contained in Table 2. For total errors, the first half of the ratio contained a reliably higher percentage of errors (52%) than the last half of the ratio (48%), (z = 1.97). Although this difference was significant as determined by a two-tailed binomial test at the .05 level, the effect was borderline (minimum z = 1.96 = .05). Win-stay, lose-shift pooled errors showed a larger percentage in the first half of the ratio (57%) than in the last half of the ratio (43%), (z = 3.04). This type of error pattern was most robust for win-shift, lose-stay errors and win-stay, lose-stay errors. Win-shift lose-shift errors were located 70% in the first half of the ratio and 30% in the last half of the ratio ($\underline{z}$ = 6.96); win-stay, lose-stay errors were located 74% in the first half of the ratio and 36% in the last half of the ratio ($\underline{z}$ = 7.72). Win-shift, lose-shift errors deviated from this pattern with more errors located in the last half of the ratio (60%) than in the first half of the ratio (50%), ($\underline{z}$ = 6.69). Again the most frequent error was the win-shift, lose-shift variety, although these were closely followed by win-stay, lose-shift errors.

Both pigeons in the simultaneous-discrimination condition produced very different error patterns than pigeons in the matching-to-sample condition. Table 2 presents the pooled error data for the first and last halves of the ratio for the simultaneous discrimination pigeons. For total errors, the first half of the ratio had a significantly lower percentage of errors (35%) than the last half of the ratio (65%), ($\underline{z}$ = 4.96). This pattern was maintained for win-stay, lose-shift errors with 25% first half ratio errors and 75% last half ratio errors ($\underline{z}$ = 5.39). Win-shift, lose-stay errors were assayed in a different pattern with a larger percentage in the first halves of ratios (85%) than in the last halves (15%). This difference was significant as indicated by a table of critical values for the binomial test for frequencies equal to or less than 50 ($p = q = 1/2$). Win-stay, lose-stay errors were located more in the last half of ratios (62%) than in the first half of ratios (38%), ($\underline{z}$ = 2.95). Win-shift, lose-shift errors, the least frequent type of error for this group, were located more in the first half of the ratio (80%) than in the last half (20%).

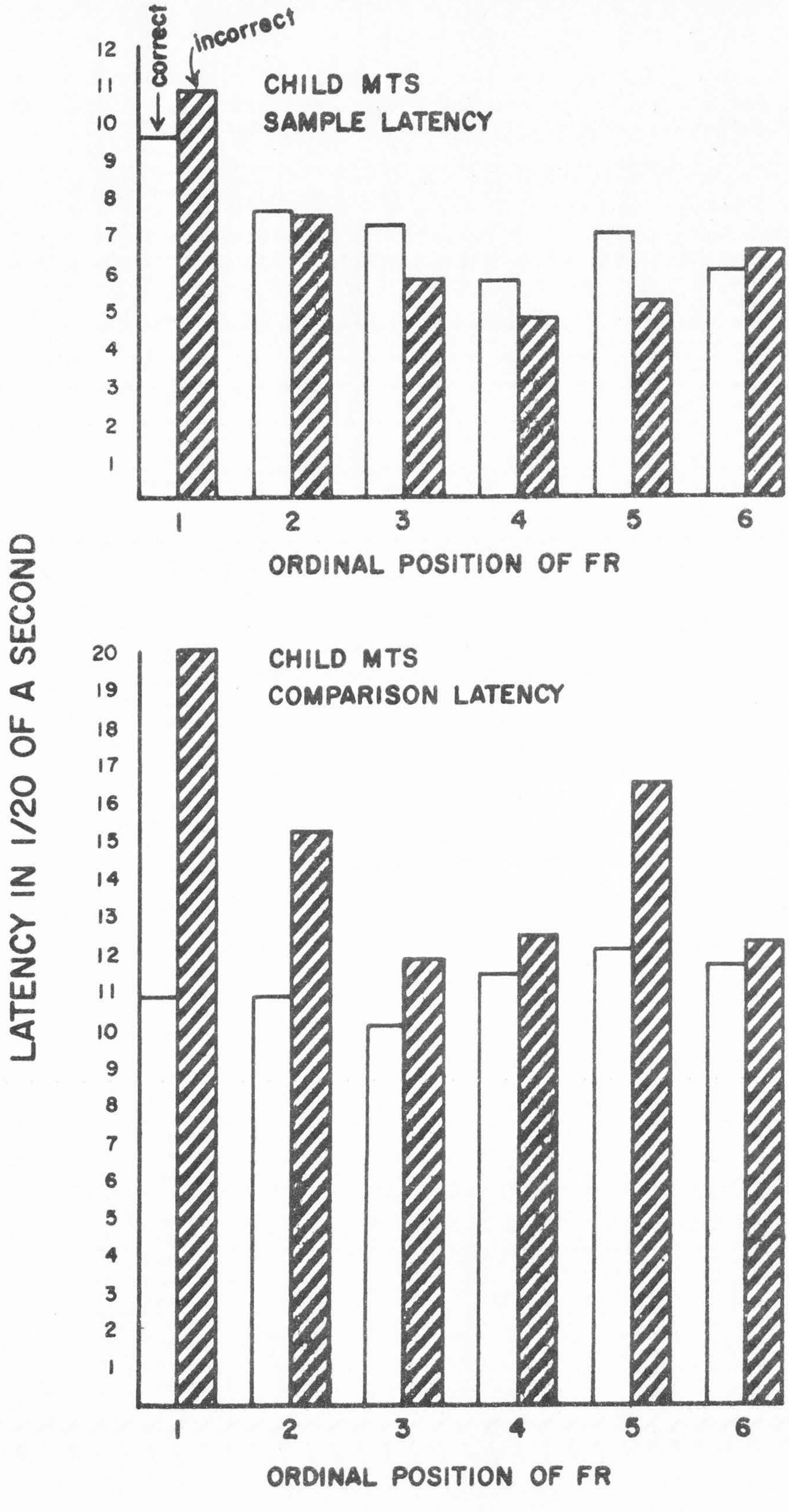
This effect was not significant as indicated by a table of critical values for the binomial test for frequencies equal to or less than 50.

In summary, all experimental groups except pigeons in the simultaneous-discrimination condition showed more first half than last half ratio total errors. The error pattern for total errors, either standard or reversed, was reliably composed of win-stay, lose-shift errors; win-shift, lose-stay; and occasionally win-stay, lose-stay errors. Win-shift, lose-shift errors did not contribute to the error patterns. The pigeons in the simultaneous discrimination group exhibited a reversed error pattern with more total errors in the last half of the ratio. Win-shift, lose-shift errors were the most frequent type of error for all groups except the pigeons in the simultaneous-discrimination condition. For this condition, the win-shift, lose-shift error was the least frequent error type.

Pooled Latency Data

The mean latency data for all children who matched-to-sample are presented in Figure 2. The data displayed in this figure are for correct (white bars) and error (striped bars) sample and comparison responses. The latency values for sample responses indicate that there were no reliable differences between correct and error responses for each ordinal position. Both correct and error sample latencies of the first ordinal position of the ratio were the longest latencies, when compared to the other ordinal positions.

Figure 2. Sample and comparison latencies for correct and error responses by ordinal position of the FR for children on matching-to-sample.


correct
incorrect
CHILD MTS
SAMPLE LATENCY
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
ORDINAL POSITION OF FR
LATENCY IN 1/20 OF A SECOND
CHILD MTS
COMPARISON LATENCY
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
ORDINAL POSITION OF FR

The comparison latencies in Figure 2 showed that error response latencies were longer than correct response latencies for every ordinal position within the FR. The first ordinal position error latencies were twice as long as the correct response latencies for comparison responses. The longest error latency occurred immediately after reinforcement while the correct comparison latencies were approximately equal across ordinal positions of the FR.

The mean latency data for the simultaneous discrimination child subjects are presented in Figure 3. The longest latency for error responses occurred in the first ordinal position of the ratio immediately after reinforcement. The longest latency for correct responses occurred in the third ordinal position. There were no systematic differences in the latencies of the correct and error response latencies across ordinal positions of the ratio, but both types of latencies tended to decrease gradually over succeeding ordinal positions of the ratio.

The pooled latency data for both matching-to-sample pigeon subjects are presented in Figure 4 for sample latencies and comparison latencies of correct and error responses. The longest latencies of correct and error responses occurred in the first ordinal position for both sample and comparison latencies. The sample response latencies for correct and error responses of the first ordinal position were approximately twice as long as the comparison latencies for correct and error responses of the first ordinal position.

Figure 3. Response latencies for correct and error responses by ordinal position of the FR for children on simultaneous discrimination.

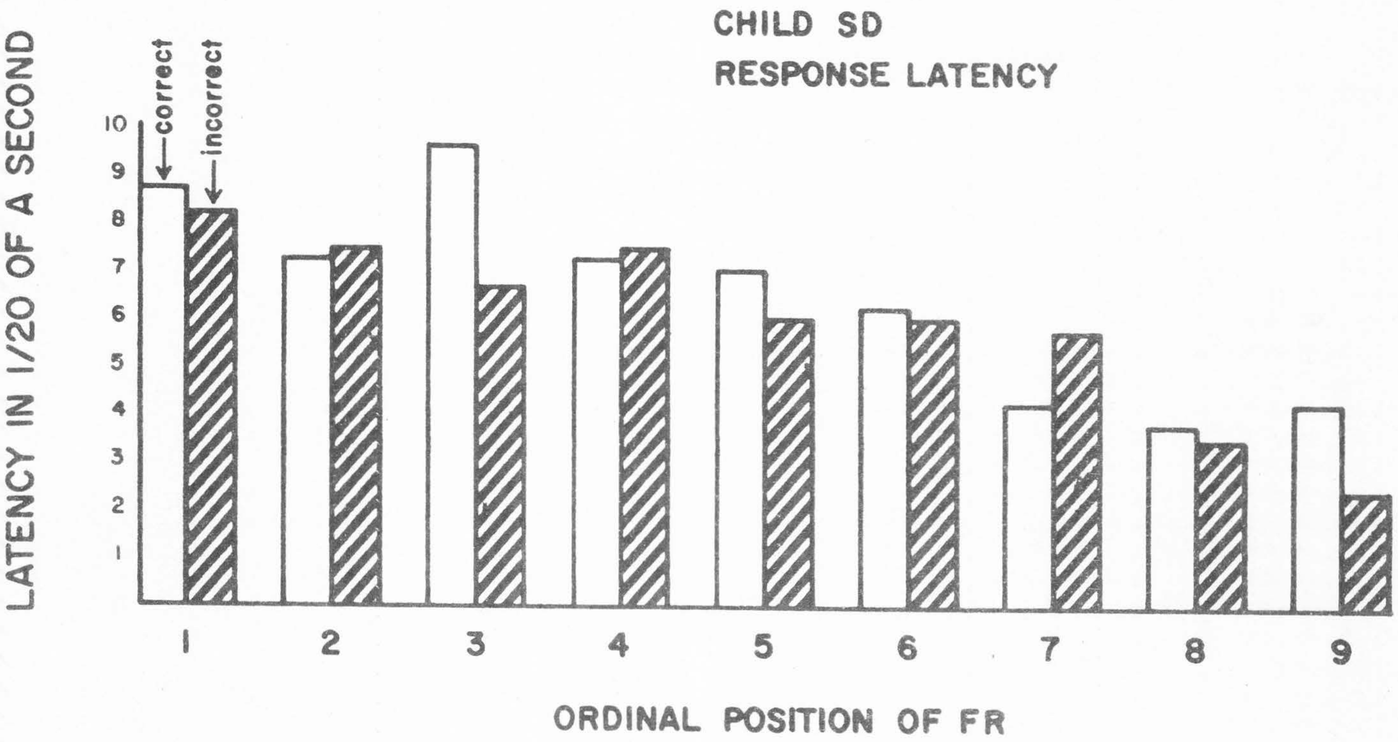
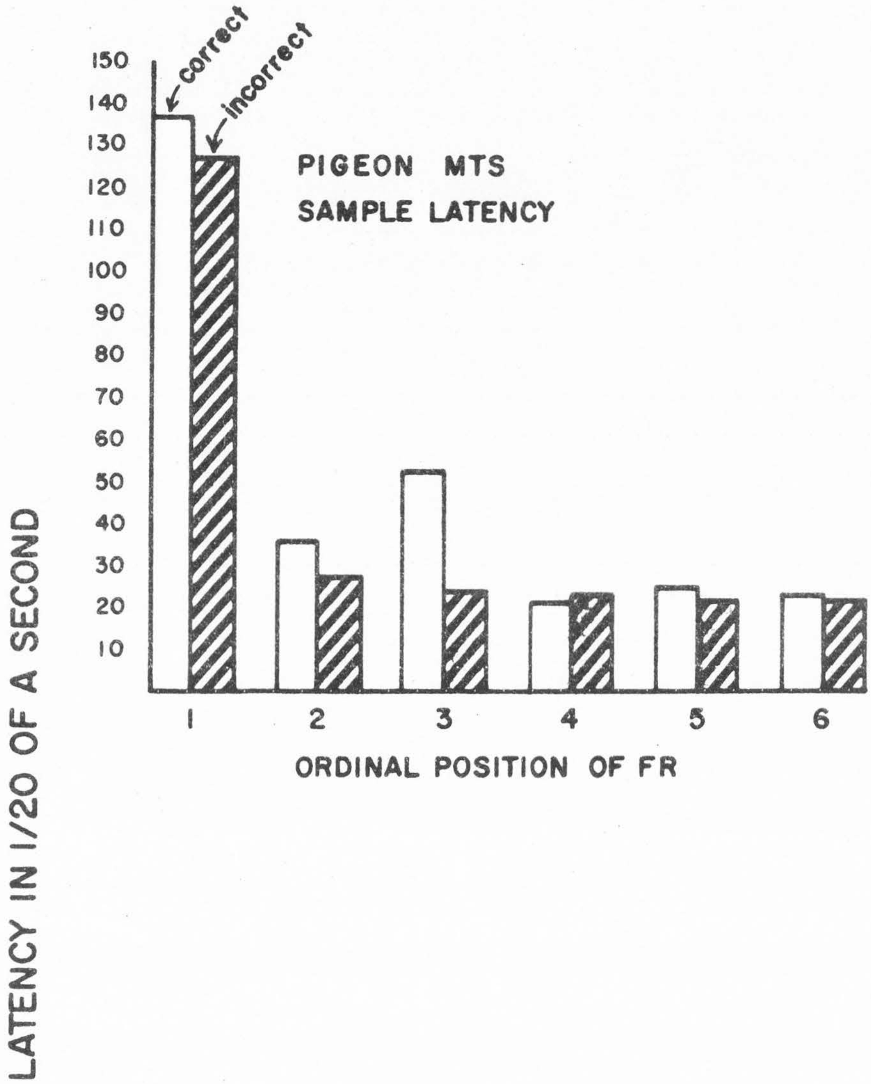
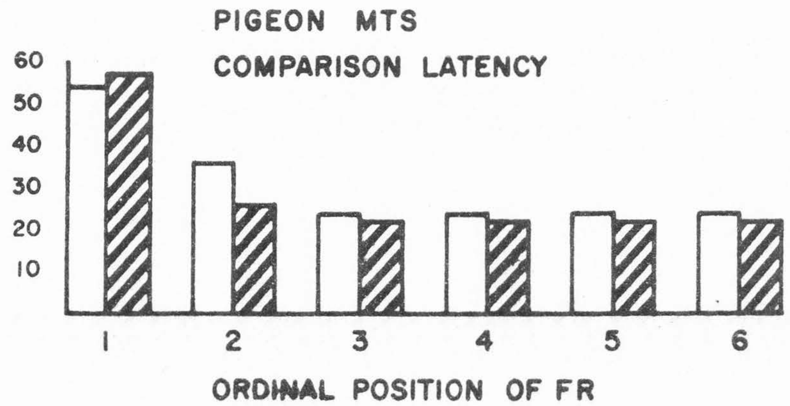

CHILD SD
RESPONSE LATENCY
LATENCY IN 1/20 OF A SECOND
correct
incorrect
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
ORDINAL POSITION OF FR

Figure 4. Sample and comparison latencies for correct and error responses by ordinal position of the FR for pigeons on matching-to-sample.


correct
incorrect
PIGEON MTS
SAMPLE LATENCY
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
ORDINAL POSITION OF FR
LATENCY IN 1/20 OF A SECOND


PIGEON MTS
COMPARISON LATENCY
60
50
40
30
20
10
1
2
3
4
5
6
ORDINAL POSITION OF FR

A comparison of correct and error latencies for sample responses indicates that for the first three ordinal positions, correct responses produced longer latencies than error responses. After the third ordinal position, this effect was lost. Correct and error-response latencies for comparison responses were approximately equal throughout the ratio.

The average latency data for both simultaneous discrimination pigeon subjects are presented in Figure 5. The difference between correct and error-response latencies was very large for the first ordinal position. For this position, error response latencies were twice as long as correct response latencies. Longer error response latencies were maintained over succeeding ordinal positions with positions 6 and 3 being exceptions. The trend for both error-response latencies and correct-response latencies was a shortening of latencies over succeeding ordinal positions.

In summary, the pooled latency data indicate that there is no consistent difference between correct and error response latencies. The longest latency for correct and incorrect responses occurred immediately after reinforcement with the latencies decreasing in succeeding ordinal positions of the ratios for both species.

Response Accuracy

For single subjects, accuracy data are presented in Table 3. This table depicts mean error scores, error standard deviations, and the

Figure 5. Response latencies for correct and error responses by ordinal position of the FR for pigeons on simultaneous discrimination.

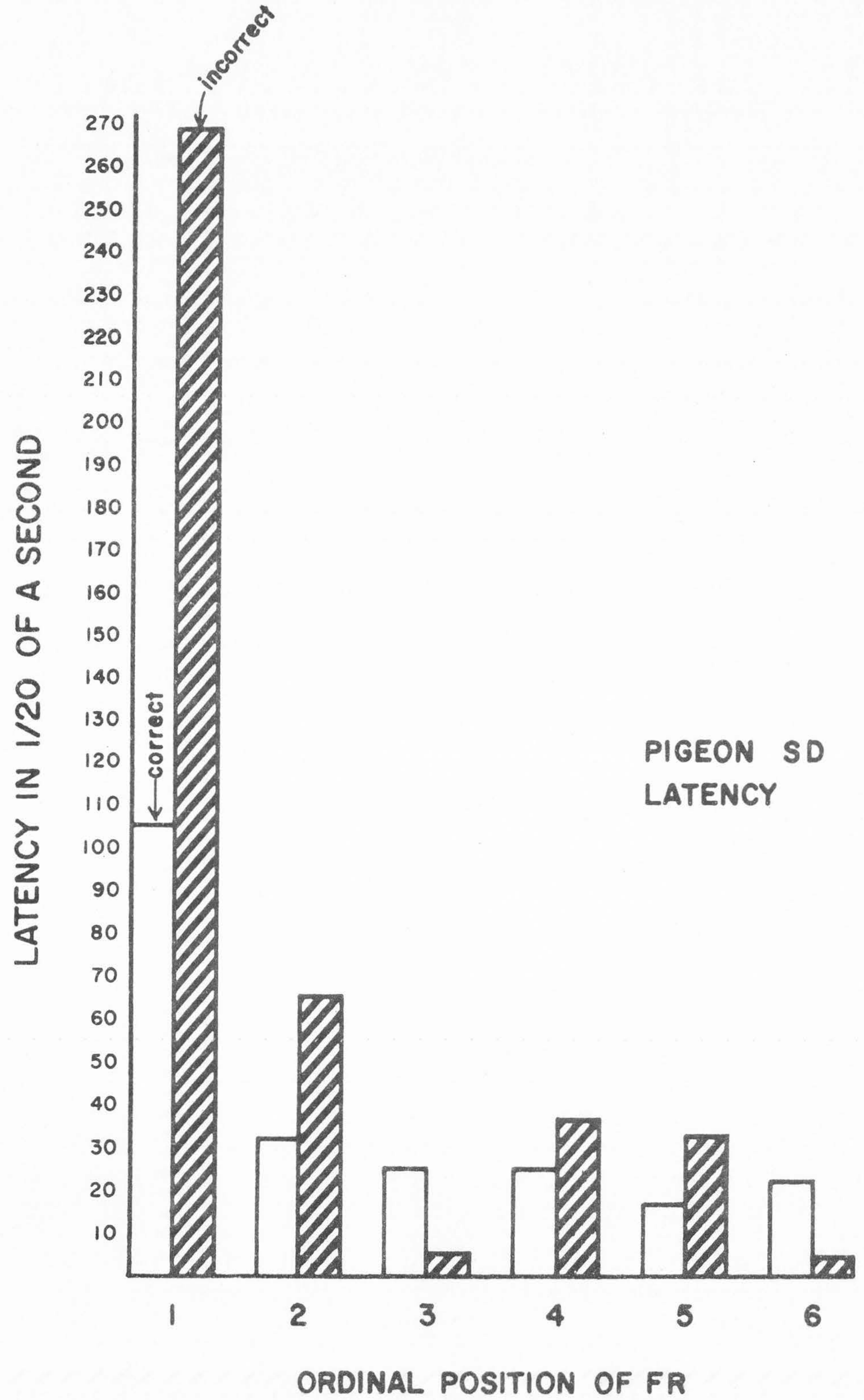

incorrect
correct
LATENCY IN 1/20 OF A SECOND
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
ORDINAL POSITION OF FR
PIGEON SD
LATENCY

Table 3

Error Means, Standard Deviations, and Proportions for Each

Experimental Condition for Each Subject

	Experimental Conditions						
	A	B	C	D	E	F	G
MTS Child Subjects							
S1							
$\overline{X}$	64.66	48.66	53.33	39.00	-	37.33	-
SD	17.24	2.31	11.59	10.14	-	4.04	-
%	25	21	23	18	-	17	-
S2							
$\overline{X}$	4.66	-	-	-	44.33	24.66	6.67
SD	1.53	-	-	-	15.59	12.50	2.31
%	03	-	-	-	20	12	03
S3							
$\overline{X}$	76.00	71.33	64.00	58.66	-	63.00	72.66
SD	9.16	10.21	6.08	3.05	-	13.45	21.57
%	46	44	42	39	-	41	45
SD Child Subjects							
S4							
$\overline{X}$	151.00	-	158.66	-	-	90.33	65.00
SD	3.00	-	21.38	-	-	9.23	9.54
%	46	-	47	-	-	33	27
S5							
$\overline{X}$	160.66	-	156.00	153.33	-	148.33	9.66
SD	6.11	-	11.53	5.51	-	17.38	4.04
%	47	-	46	46	-	45	05
S6							
$\overline{X}$	7.33	14.00	16.66	18.66	17.00	7.33	10.66
SD	2.88	6.93	2.08	14.84	8.72	5.03	3.21
%	02	05	06	06	06	03	04

Table 3

Continued

	Experimental Conditions						
	A	B	C	D	E	F	G
MTS Pigeon Subjects							
S7							
$\overline{X}$	126.67	-	-	141.33	-	124.00	-
SD	14.01	-	-	15.27	-	4.58	-
%	.41	-	-	.44	-	.41	-
S8							
$\overline{X}$	146.33	-	-	-	141.66	-	143.00
SD	18.58	-	-	-	5.51	-	13.52
%	.45	-	-	-	.44	-	.44
SD Pigeon Subjects							
S9							
$\overline{X}$	0	-	-	6.00	-	2.33	7.66
SD	0	-	-	4.35	-	2.51	1.52
%	0	-	-	03	-	.01	.04
S10							
$\overline{X}$	26.00	-	-	-	11.66	8.66	32.66
SD	10.81	-	-	-	3.78	3.21	14.74
%	.13	-	-	-	06	.05	.15

percentage of errors in comparison to the total number of responses for all subjects for all experimental conditions.

For S1 in the matching-to-sample condition experimental condition A produced the largest percentage of errors (25%) and condition F the smallest percentage of errors (17%). Condition C produced the largest standard deviation score of 11.59 while condition B produced the smallest score of 2.31. For S2 in this group the lowest percentage of errors occurred for conditions A and G (3% and 3%), while the largest percentage of errors occurred for condition E (20%). Conditions A and G also produced the smallest standard deviations (1.53 and 2.31), and condition E produced the largest standard deviation score (15.59). A comparison of all three child matching-to-sample subjects (S1, S2, and S3) in Table 3 shows that S2 had on the average the smallest error percentages for each of the experimental conditions. For S3, condition A produced the largest percentage of errors (46%) while condition D had the smallest percentage of errors (39%). Standard deviation scores varied over conditions with condition D having the smallest score (3.05) and condition G the largest score (21.57).

The subject data for children on the simultaneous-discrimination condition are also presented in Table 3. For S4 it can be seen from this table that condition G produced the smallest error percentage and that condition C produced the largest error percentage. Error response variability as represented by standard deviation scores was largest for condition C (21.38) and smallest for condition A (3.00). For S5, error percentages were fairly constant (47%, 46%, 46%, and 45%) for all conditions A, B, C, and F but not for condition G. Condition G had an error percentage (5%) that was much smaller than the other experimental conditions. Condition G also had the smallest error standard deviation (4.04) while condition F the largest error standard deviation (17.38). Subject S6 was the most accurate subject of the children performing the simultaneous discrimination (Table 3). This table shows that condition A and F produced the smallest error percentage (2% and 3%) while condition D produced the largest error percentages (6%). Error standard deviation scores were very small for experimental conditions except condition D (14.84).

The pigeon subjects' (S7 and S8) accuracy data for matching-to-sample are presented in Table 3. For S7, the error percentages for all three conditions, A, D, and F, were approximately the same (41%, 44%, and 41%). Condition D produced the largest error standard deviation score (15.27) while condition F produced the smallest score (4.58). Subject S8 produced error percentages for experimental conditions A, D, and G which were approximately equal (45%, 44%, and 44%). Condition A had the largest error standard deviation (18.58) and condition E the smallest error standard deviation score (5.51).

Subjects S9 and S10 were pigeon subjects on simultaneous discrimination. In condition A, S9 made no errors although it was in this condition for a total of 11 sessions. The condition with the largest error percentage was condition G (5%). This condition also had the smallest error standard deviation score (1.52). Condition F had the smallest error percentage (1%).

Condition D had the largest error standard deviation score of 4.35. For S10, condition G produced the largest error percentage (15%) and error standard deviation score (14.74). Condition F produced the smallest error percentage score (5%) and error standard deviation score (3.21).

In summary the accuracy analysis in Table 3 shows that all subjects were under the control of the programmed tasks. In all cases, responding was above chance. In some cases, the above chance responding was marginally above chance. However, the procedure was designed to generate errors so the high error rates were not unexpected. The experimental conditions did not systematically relate to error percentages within subjects.

Two-Trial Error Analysis

Matching-to-Sample Children

A separate two-trial error analysis is presented in Figure 6 for S1. In this figure win-stay and win-shift errors are plotted as the complement of each other and lose-stay and lose-shift errors are plotted as the complement of each other for each experimental condition. A win-shift and win-stay error comparison shows that S1 made a majority of win-shift errors across all experimental conditions. A lose-shift and lose-stay error comparison indicated that S1 made more lose-shift errors on all experimental conditions except D. S1's error performance in all conditions was predominately of the win-shift, lose-shift variety.

Figure 6. Two-trial error percentages across experimental conditions for child subject S1 on matching-to-sample.

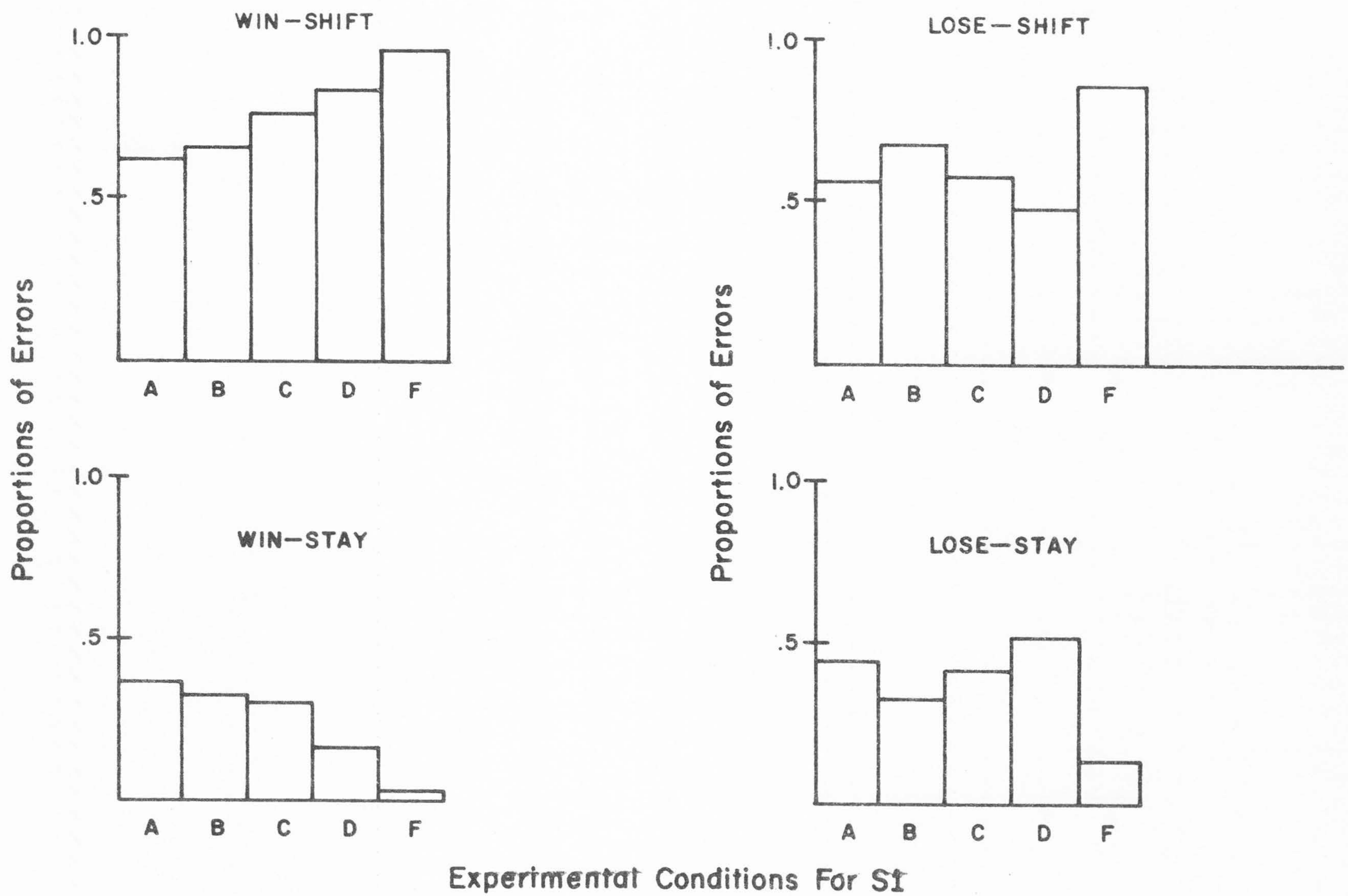

WIN-SHIFT
LOSE-SHIFT
WIN-STAY
LOSE-STAY
Proportions of Errors
Proportions of Errors
1.0
.5
A
B
C
D
F
Experimental Conditions For S1

Figure 7 indicates that most errors occurred in the win-stay category when win-shift and win-stay errors were compared for S2. A comparison of lose-shift and lose-stay errors showed that S2 produced only 42% lose-shift errors as opposed to 58% lose-stay errors. An overall error preference analysis from Figure 7 suggests that S2 favored win-stay and lose-stay errors in comparison to win-shift and lose-shift errors.

Figure 8 shows that S3 displayed a majority of win-shift errors in a comparison of win-shift and win-stay errors. S3 displayed many more lose-shift errors than lose-stay errors. Figure 8 suggests that over experimental conditions S3 made more win-shift and lose-shift errors than win-stay or lose-stay errors.

Simultaneous-Discrimination Children

A two-trial error analysis is presented in Figure 9 for S4. S4 made more win-shift errors than win-stay errors in conditions C (66%) and F (87%) and more win-stay errors than win-shift errors in conditions A (76%) and G (62%). A lose-shift and lose-stay error comparison showed that S4 had more lose-shift errors than lose-stay errors for all experimental conditions. In summary, subject S4 made more lose-shift errors than lose-stay errors irrespective of experimental conditions. But win-shift or win-stay error percentages were determined by experimental conditions.

A two-trial error analysis presented in Figure 10 showed that S5 emitted a majority of win-shift errors in comparison to win-stay errors for

Figure 7. Two-trial error percentages across experimental conditions for child subject S2 on matching-to-sample.

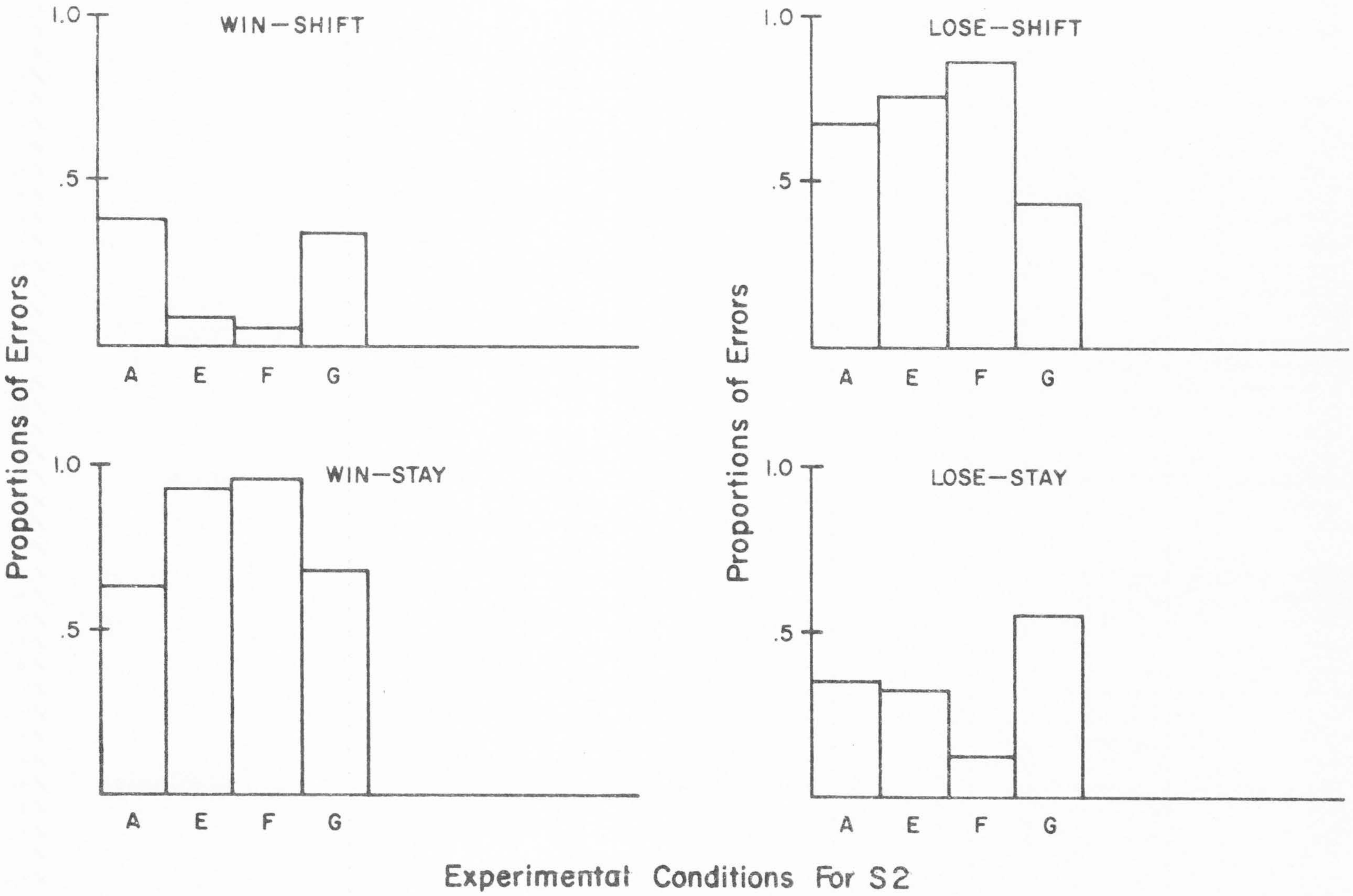

WIN—SHIFT
LOSE—SHIFT
WIN—STAY
LOSE—STAY
1.0
.5
A E F G
Proportions of Errors
Experimental Conditions For S2

Figure 8. Two-trial error percentages across experimental conditions for child subject S3 on matching-to-sample.

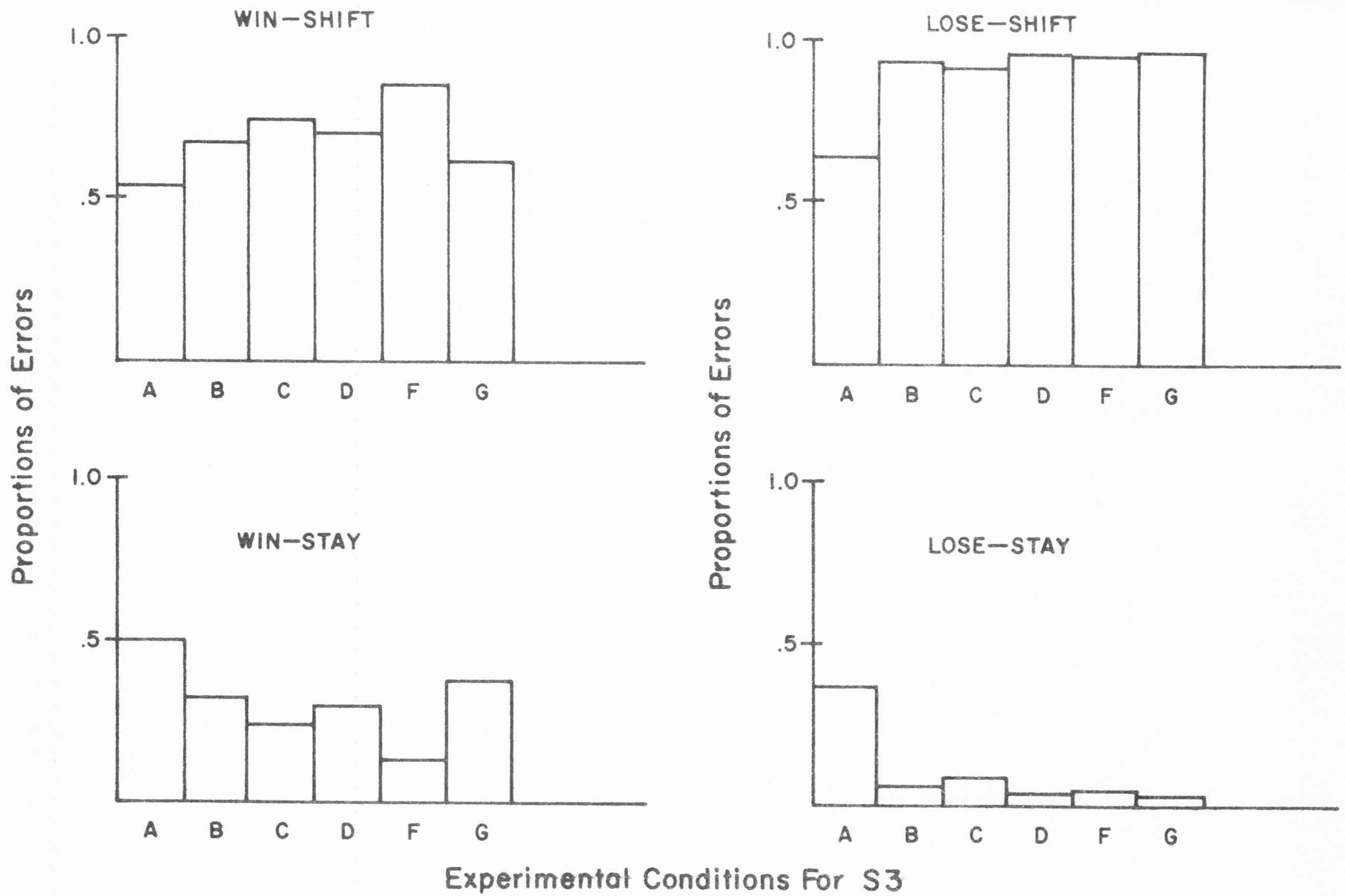

WIN—SHIFT
LOSE—SHIFT
WIN—STAY
LOSE—STAY
1.0
.5
Proportions of Errors
A B C D F G
Experimental Conditions For S3

Figure 9. Two-trial error percentages across experimental conditions for child subject S 4 on simultaneous discrimination

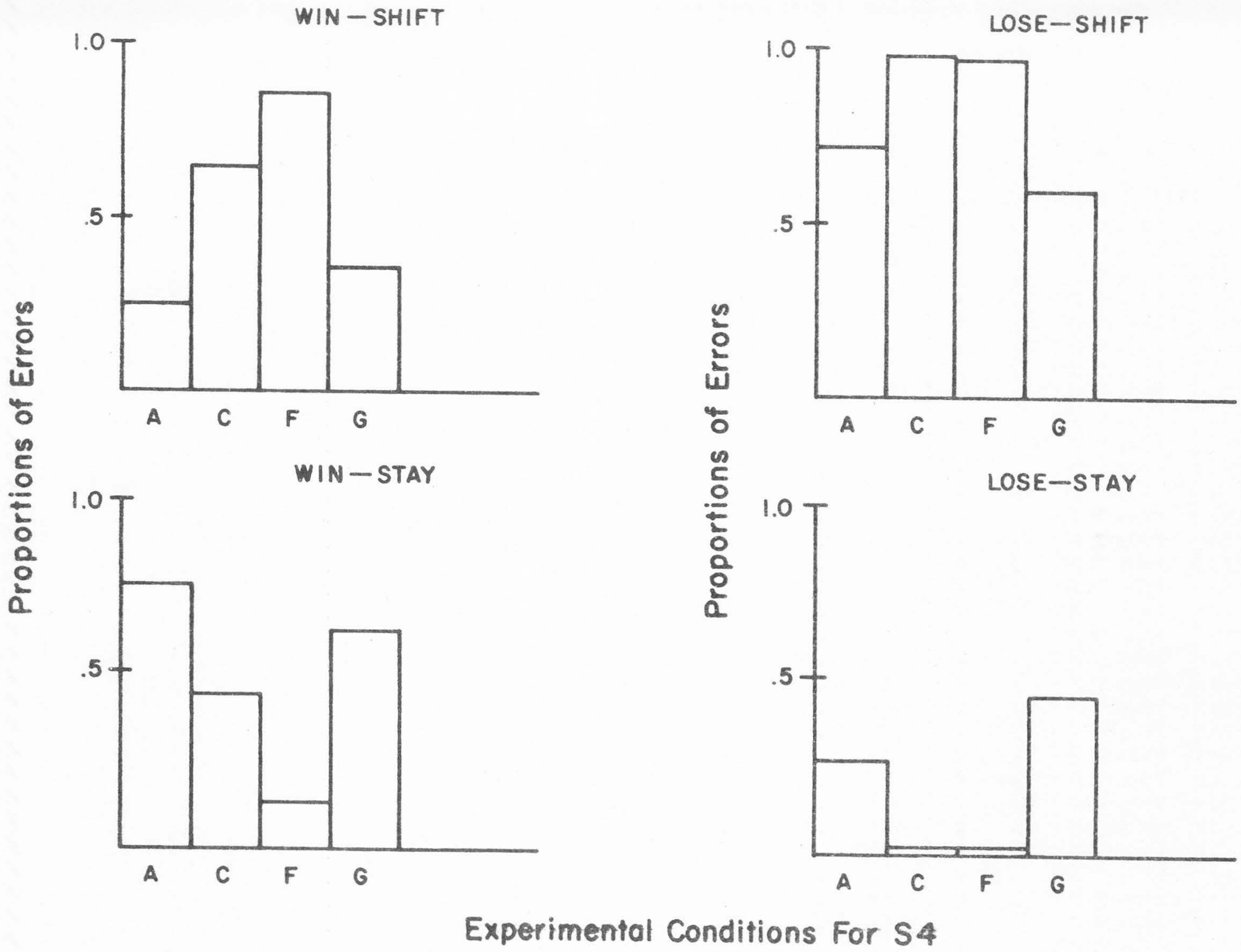
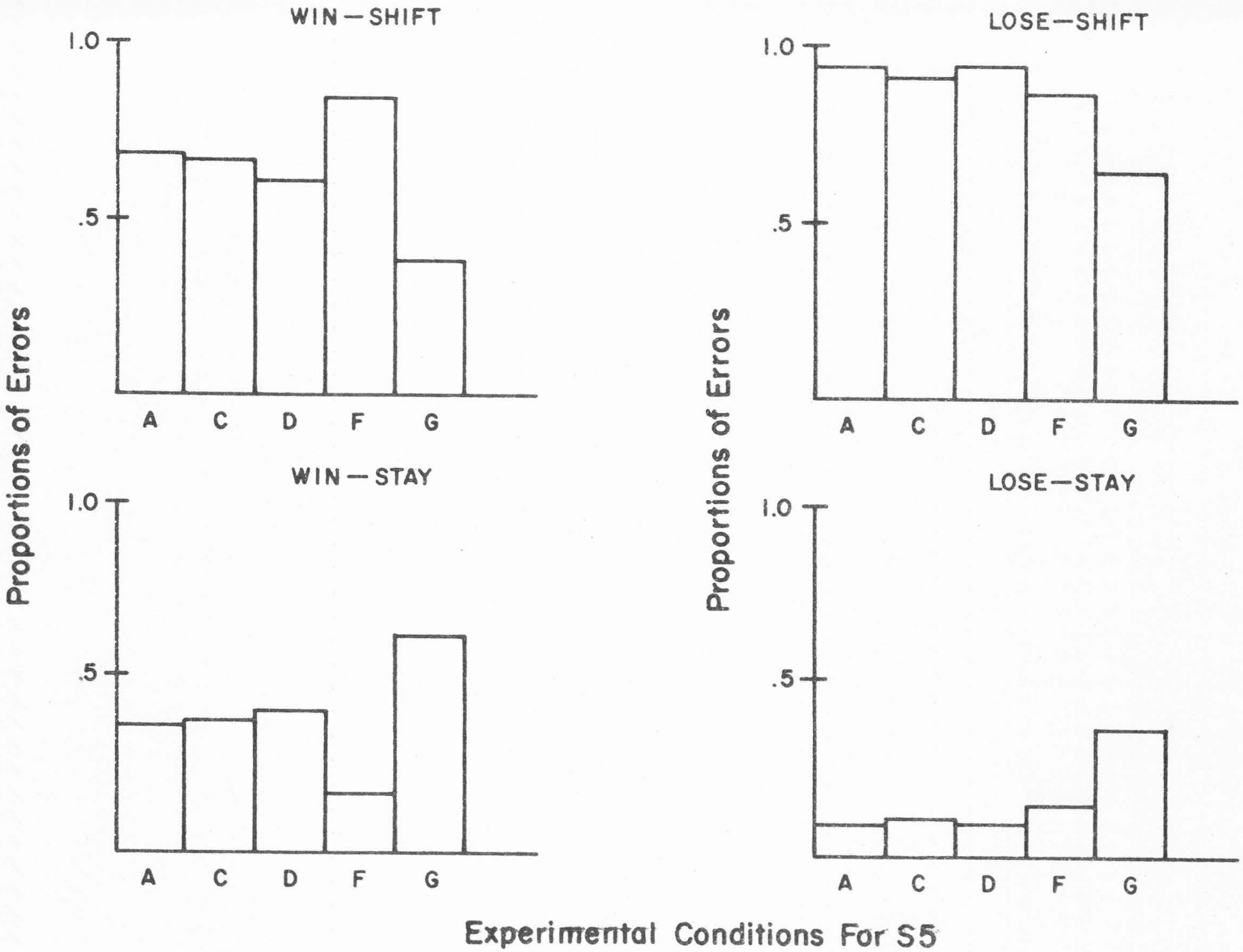

WIN — SHIFT
LOSE—SHIFT
WIN — STAY
LOSE—STAY
Proportions of Errors
Proportions of Errors
1.0
.5
A
C
F
G
Experimental Conditions For S4

Figure 10. Two-trial error percentages across experimental conditions for child subject S5 on simultaneous discrimination


WIN—SHIFT
LOSE—SHIFT
WIN—STAY
LOSE—STAY
Proportions of Errors
1.0
.5
A C D F G
Experimental Conditions For S5

all conditions except condition G. A lose-stay and lose-shift error comparison showed that S5 made more lose-shift errors across all experimental conditions. S5's performance was largely based on win-shift, lose-shift errors.

Figure 11 shows that S6 produced more win-stay errors than win-shift errors across all conditions. S6 made more lose-shift errors than lose-stay errors except in condition G. S6 behaved predominately according to win-stay and lose-shift hypotheses throughout.

Matching-to-Sample Pigeons

Pigeon subject S7 made more win-shift errors for all experimental conditions in a two-trial error analysis (Figure 12). Figure 12 shows that a greater percentage of lose-shift errors occurred when lose-shift and lose-stay errors were compared. S7 behaved predominately according to win-shift and lose-shift hypotheses.

Figure 12 shows that S8 made generally more win-shift errors than win-stay errors across experimental conditions. A comparison of lose-shift errors showed that S8 produced many more lose-shift errors. Thus this pigeon too behaved according to win-shift and lose-shift hypotheses.

Simultaneous-Discrimination Pigeons

Figure 13 shows the two-trial analysis by experimental conditions for simultaneous-discrimination pigeons, S9 and S10. In a win-shift and win-stay error comparison S9 made more win-stay errors for all conditions

Figure 11. Two-trial error percentages across experimental conditions for child subject S6 on simultaneous discrimination.

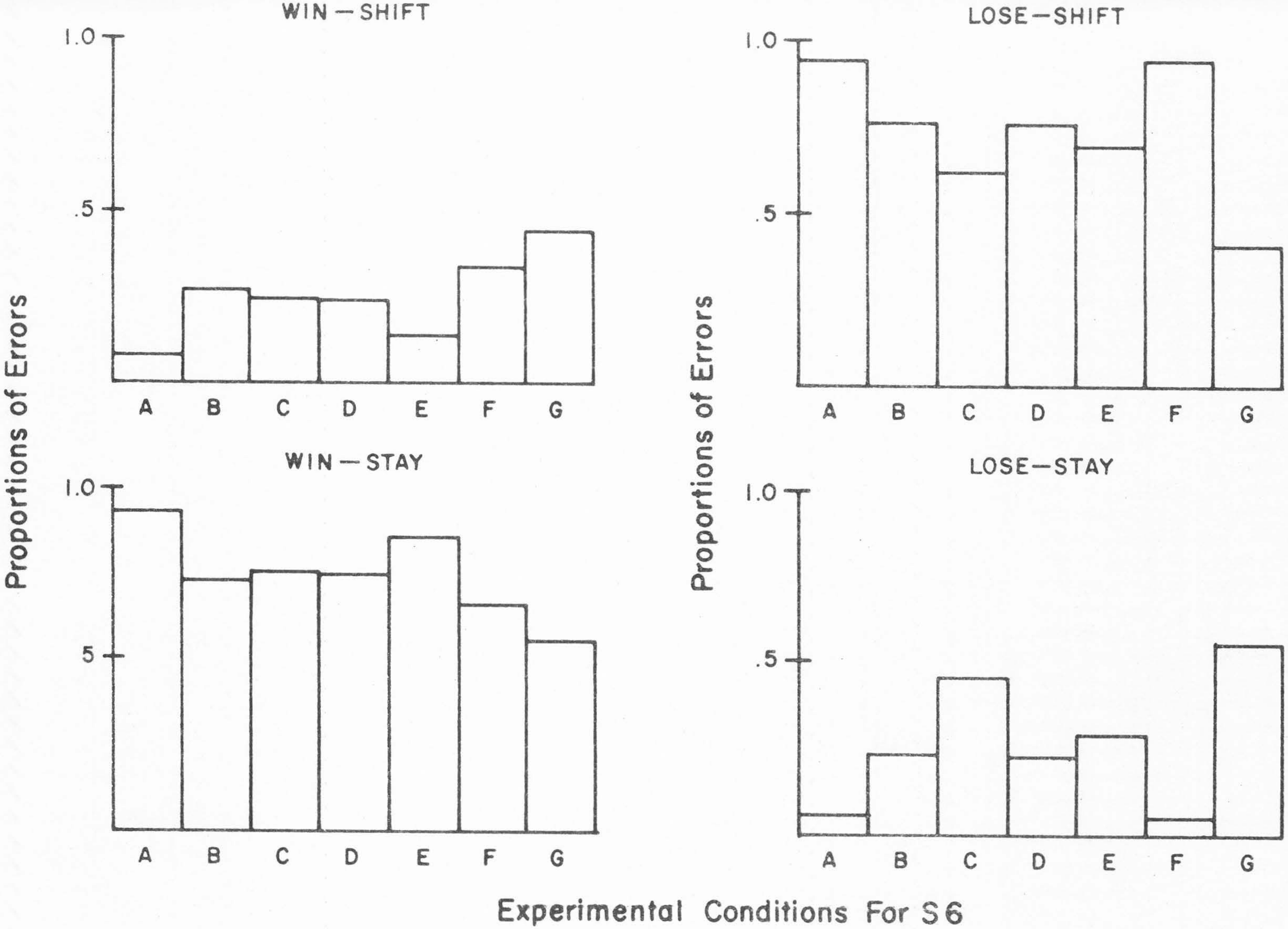
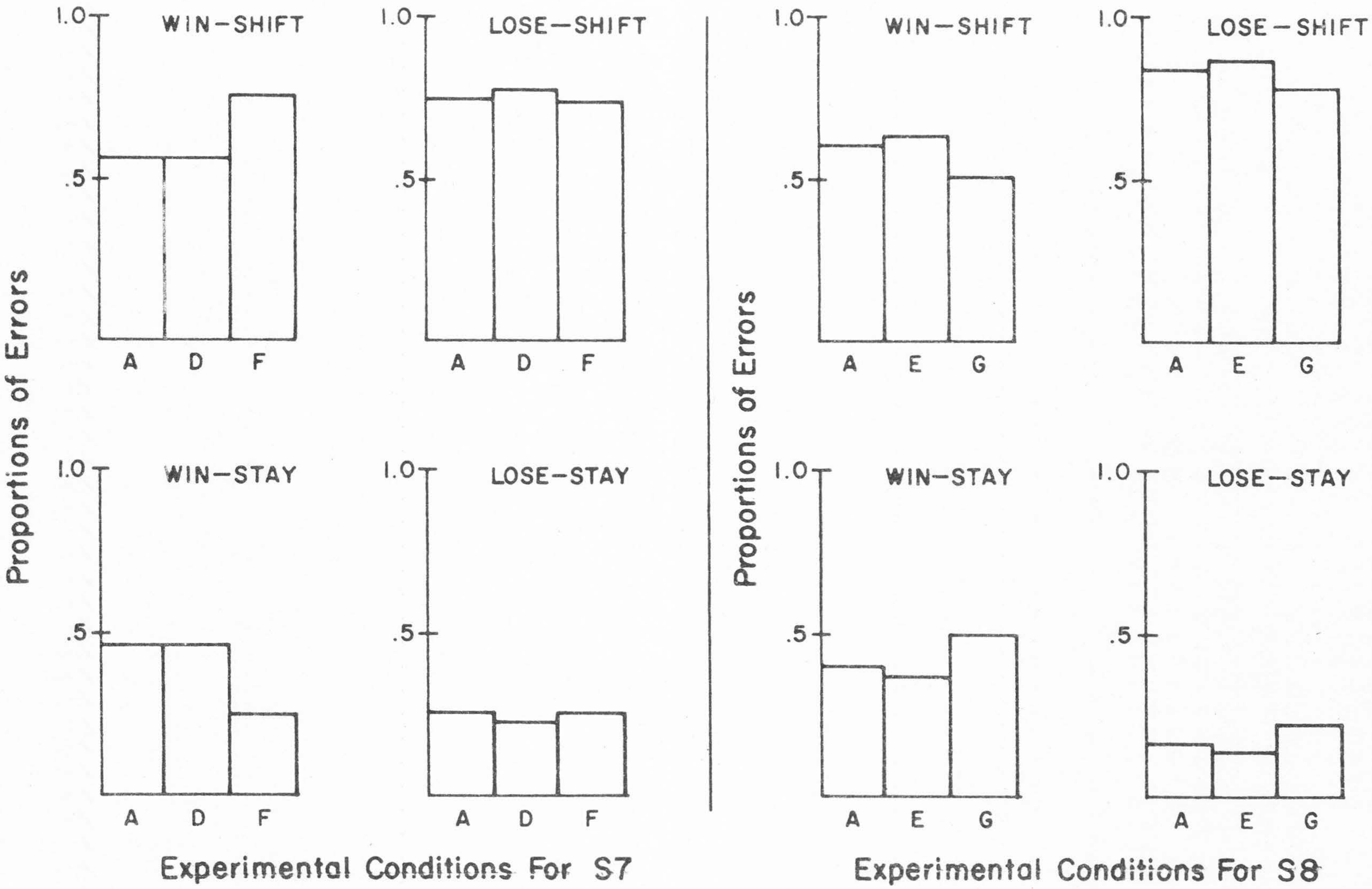
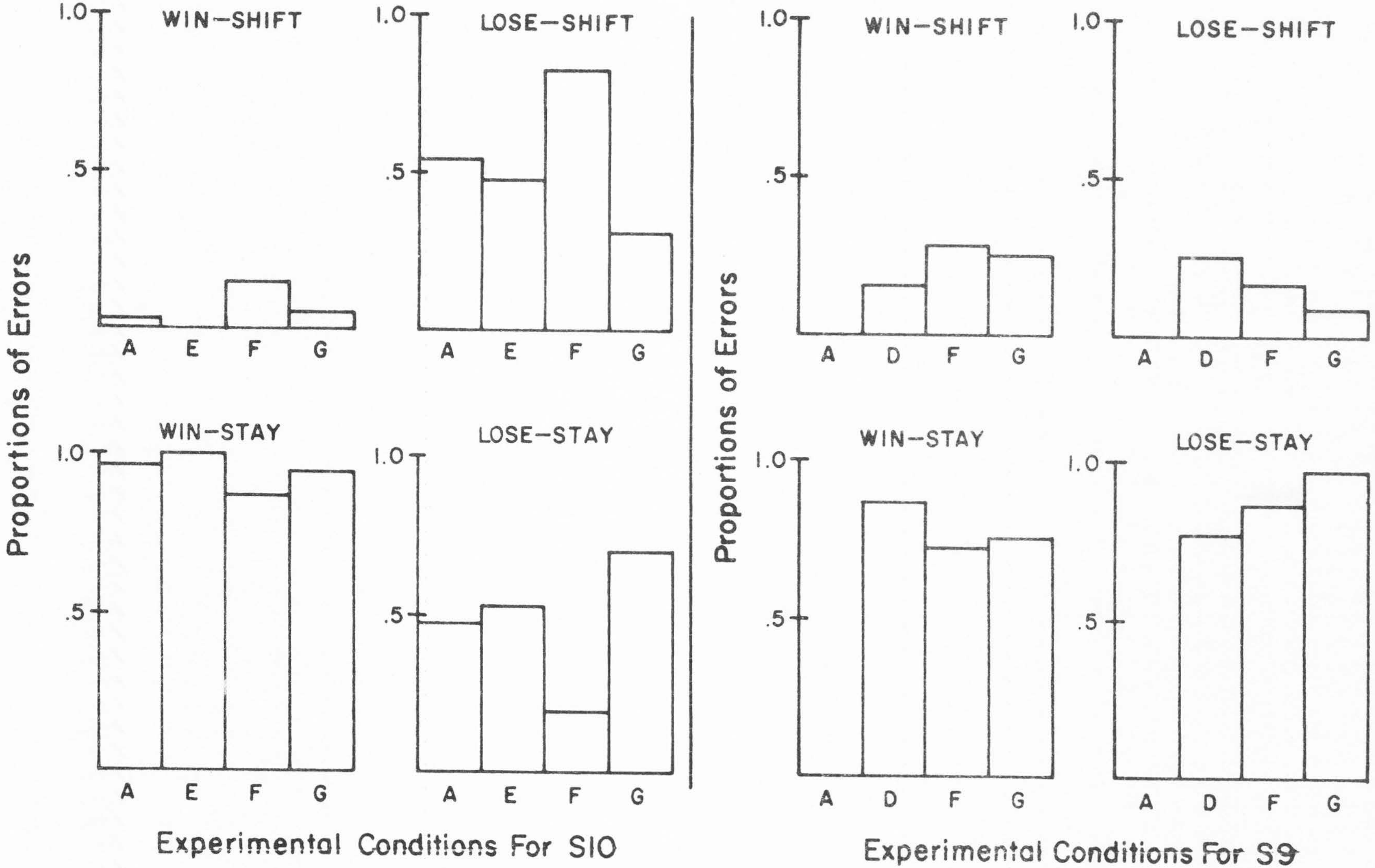

WIN — SHIFT
LOSE—SHIFT
WIN — STAY
LOSE—STAY
1.0
.5
5
Proportions of Errors
A B C D E F G
Experimental Conditions For S6

Figure 12. Two-trial error percentages across experimental conditions for pigeons subjects S7 and S8 on matching-to-sample.



WIN-SHIFT
LOSE-SHIFT
WIN-STAY
LOSE-STAY
1.0
.5
A D F
A E G
Proportions of Errors
Experimental Conditions For S7
Experimental Conditions For S8

Figure 13. Two-trial error percentages across experimental conditions for pigeons subjects S9 and S10 on simultaneous discrimination.


Proportions of Errors
WIN-SHIFT
LOSE-SHIFT
WIN-STAY
LOSE-STAY
1.0
.5
A E F G
Experimental Conditions For S10
Proportions of Errors
WIN-SHIFT
LOSE-SHIFT
WIN-STAY
LOSE-STAY
1.0
.5
A D F G
Experimental Conditions For S9

where errors occurred. A lose-shift and lose-stay comparison indicated that many more lose-stay errors were made across experimental conditions. This bird's hypotheses were win-stay and lose-stay throughout.

The two-trial analysis presented in Figure 13 shows that in a win-stay and win-shift error comparison S10 made many more win-stay errors. A lose-shift and lose-stay comparison indicated that preference for these errors was determined by experimental conditions. Conditions A and E produced approximately equal numbers of lose-shift (53% and 49%) and lose-stay errors (47% and 51%). Condition F had many more lose-shift errors (81%) than lose-stay errors (19%). Condition G had many more lose-stay errors (70%) than lose-shift errors (30%).

In summary, the two-trial error analysis showed that each subject's error performance could be ascribed to a single hypothesis such as a lose-shift as opposed to a lose-stay or a win-stay as opposed to a win-shift hypothesis. Predominant hypotheses were for the most part uninfluenced by the experimental conditions. A total of nine subjects predominately preferred a lose-shift hypothesis to a lose-stay hypothesis and five subjects preferred the win-shift hypothesis while four subjects preferred a win-stay hypothesis.

General Summary

1. Error patterns were uneffected by experimental conditions.

2. Each subject evidenced error patterns when total errors were divided into specific error types.

3. Total errors showed weak or no error patterns for pooled data because of an averaging effect. Some error types such as win-stay, lose-shift errors showed good standard error patterning while other high frequency errors such as win-shift, lose-shift errors showed no error patterning thus hiding the patterning effect when errors were pooled.

4. The latency data indicated that for all latency measures, the longest latencies occurred immediately after reinforcement. No consistent latency differences were found between correct and incorrect responses.

5. A two-trial error analysis indicated that single hypotheses such as lose-shift errors were predominately favored by subjects and uninfluenced by experimental conditions.

DISCUSSION

Error patterns and response strategies are two behavioral phenomena which have been studied separately in the past. Osborne and Burns (1975) have suggested that error patterning might be a function of selectively reinforcing different types of response strategies. The experiments reported here are the first to examine error patterning in relation to the selective reinforcement of response strategies. This was the main emphasis for the present research. A secondary question investigated was the manipulability of response strategies.

Error Patterns

Error patterns for pooled data in which a larger proportion of errors occurred in the first half of the ratio than in the last half of the ratio were found for total errors for all experimental groups except pigeons on simultaneous discrimination. This type of error pattern was remarkably stable across species and discrimination paradigms. First half ratio errors for total errors did not differ by more than 2% for children on matching-to-sample, children on simultaneous discrimination, and pigeons on matching-to-sample. This type of pattern is consistent with other work employing children on matching-to-sample (Davidson & Osborne, 1974), children on simultaneous discrimination (Osborne & Burns, 1975), and pigeons on matching-to-sample (Nevin et al., 1963).

The error pattern for pooled data for pigeons on simultaneous discrimination was anomalous to the other experimental groups. This pattern for total errors was inverted with a greater proportion of errors in the last half of the ratio than in the first half of the ratio. Overall this group of subjects made fewer errors than the other experimental groups, and was thus more accurate in forming a discrimination. In fact, this group made a tenth of the total errors of the other three experimental groups. This result is at variance with previous findings by Zeller (1968) who found standard error patterns produced by accurate pigeon subjects on simultaneous discrimination.

A separation of total errors into specific error types can help explain error patterning by examining error types as building blocks of the total error patterns. The children on matching-to-sample showed very good error patterning across win-stay, lose-shift and win-shift, lose-stay errors for pooled data. But no significant error patterning occurred across win-stay, lose-stay or win-shift, lose-shift errors. The win-shift, lose-shift errors were by far the most frequent type of errors for these subjects. The children on simultaneous discrimination showed excellent error patterning across all error types except win-shift, lose-shift errors. The win-shift, lose-shift errors were again the most frequent error type and produced very poor error patterns. The pigeons on matching-to-sample showed good error patterning across all error types except win-shift, lose-shift errors which were the most frequent error type. But the pigeons on matching-to-sample exhibited a reversed error pattern for the win-shift, lose-shift errors.

For these three experimental groups, it is apparent that the win-shift, lose-shift errors are a common element that undermines error patterning for total errors. The win-shift, lose-shift error is a form of single alternation stereotype that has been reported by a number of investigators (Jeffery & Cohen, 1965; Schusterman, 1964; Weir, 1964) to be very frequent in two-choice discrimination tasks involving children. The high frequency of win-shift, lose-shift errors reported in this research agrees well with the literature on single alternation errors. The disruptive influence of this type of error on total error patterning is a new finding. When all four error types are combined, the more numerous win-shift, lose-shift errors have a flattening effect on the error pattern for total errors.

The pigeons on simultaneous discrimination that produced a reversed error pattern for total errors had very few win-shift, lose-shift errors when the pooled data were examined. For these subjects the win-shift, lose-shift errors occurred with a lower frequency than any other type error. Win-shift lose-stay errors were the next lowest frequency class. These subjects effectively reduced the occurrence of both types of win-shift errors and in doing so became the most accurate responders. The most common errors for these subjects were win-stay, lose-shift and win-stay, lose-stay errors. These types of errors were distributed in a reversed error pattern.

The results from the pooled subject data for all four experimental groups are similar in process to Harlow's (1959) "error factor" theory of learning. In essence, Harlow's theory suggests that learning might be a process of eliminating specific classes of errors. When all errors are eliminated according to Harlow's theory we have an asymptotic learning state.

The present data indicates that win-shift, lose-shift errors are very prevalent in the less accurate subjects. But this type of error is the least prevalent error for accurate pigeon subjects in simultaneous discrimination. These results suggest that win-shift, lose-shift errors have been eliminated by the simultaneous discrimination pigeon group leaving a more resistant core of win-stay, lose-shift and win-stay, lose-stay errors. This core of errors is a large contributor to the reversed error patterning of this experimental group.

An examination of single subject data and particularly the data from a subject who moves from inaccuracy would test and provide a fine grain examination of the error elimination conclusion derived from the pooled data. An example of this single subject methodology, can be found in Osborne and Burns' (1975) work with children in simultaneous discrimination. Osborne and Burns observed a serendipitous finding in which a single subject switched his major response strategy with a resulting shift in the type of error pattern exhibited. The shift was from a majority of win-shift errors to a majority of win-stay errors with a concomitant shift to more first-half errors in the ratio than the last-half of the ratio.

The children on matching-to-sample showed two basic error patterns, standard and reversed, each of which were associated with different high frequency response strategies. For example, subjects S1 and S3 showed poor total error patterns, but a majority of standard error patterns when total errors were separated into types across experimental conditions. The reason that there was poor total error patterning can be explained by high frequencies of win-shift, lose-shift errors. These errors were the most frequent error for these two subjects, and the win-shift, lose-shift errors did not correlate with any type of error pattern. Subject S2, the most accurate matching-to-sample subject, produced a majority of reversed error patterns across experimental conditions when total errors were separated into error types. The win-stay, lose-stay errors where the most frequent error type for this subject, and also resulted in reversed error patterns for three of the four experimental conditions. Win-shift, lose-shift errors were the least frequent error for this subject.

The association of standard error patterns and reversed patterns with different high frequency response strategies was also maintained for children on simultaneous discrimination. Subject S4 had a slight majority of standard error patterns across experimental conditions when the total errors were separated into error types. The standard error patterns for this subject were separated by at least a 14 error difference between the first and last halves of the ratio. Reversed error patterns were separated at most by a two-error difference between the first and last halves of the ratio. This result suggests that standard error patterns were far more robust for subject S4. Win-shift, lose-shift errors were the most frequent type of error for this subject, and only one experimental condition for this error fit an error patterning definition. Subject S5 exhibited a clear majority of standard error patterns across experimental conditions. Along with the increase in response accuracy, there was a shift in error patterning from the standard error patterning exhibited by the other experimental conditions to a majority of reversed error patterns by error types for condition G. The number of win-shift, lose-shift errors was decreased to the second least frequent error type for condition G. The win-shift, lose-shift errors for the other experimental conditions were clearly the most frequent error types. Subject S5 was similar to the serendipitous subject of the Osborne and Burns (1975) study. Subject S6 produced a majority of standard error patterns across experimental conditions when total errors were separated into types. But all error patterning for this subject was not robust, generally the first and last half ratio errors were separated by one or two errors. The total errors did not exhibit consistent error patterning effects. For total errors, two experimental conditions showed standard error patterning; one experimental condition showed reversed error patterning; and four experimental conditions showed no error patterning. This subject's nonpatterning for total errors could possibly be a function of what Davidson and Osborne (1974) considered as not reaching an error limit threshold. According to Davidson and Osborne, a limited but definite number of errors was needed to produce error patterns. Below this level no error patterns occurred; above this level error patterns formed for cyclic schedules of reinforcement.

Additional support for the notion that error patterns are differentially affected by diverse response strategies is provided by the pigeon data. The pigeons on matching-to-sample produced majorities of standard error patterns across experimental conditions when total errors were separated into error types. The total errors for all experimental conditions for both matching-to-sample pigeon subjects showed no error patterning. This lack of error patterning can again be traced to the win-shift, lose-shift errors. The win-shift, lose-shift errors were the most frequent error type plus they exhibited a clear majority of reversed error patterning across experimental conditions. The data from the pigeons on simultaneous discrimination were of two types. S9 produced very few total errors and very poor error patterning. The majority of error patterns for S9 was of the standard type, but the error patterning was not robust. S10 produced a clear majority of strong reversed error patterns across experimental conditions. Both S9 and S10 exhibited very few win-shift, lose-shift type errors.

The relations between error patterns and response strategies lead to a number of conclusions. For both species of subjects in this experiment, when relatively large numbers of errors were produced they were largely composed of win-shift, lose-shift errors. When lower frequencies of errors were produced the errors were largely win-stay, lose-shift and win-stay, lose-stay errors with very few win-shift, lose-shift errors. When relatively large frequencies of errors were produced, the standard error pattern was masked for total errors by the win-shift, lose-shift errors. But the standard error patterning was found in win-stay, lose-shift errors when total errors were separated into types. When the accuracy of responding increased, win-shift, lose-shift errors decreased in frequency leaving win-stay, lose-shift errors and win-stay, lose-stay errors as the most frequent errors. If the number of errors decreased even more, error patterns were either lost or very weak adding credence to the Davidson and Osborne (1974) notion of an error pattern threshold.

The lack of good error patterning across all ordinal positions of the ratio must be addressed. Nevin et al. (1963) and Mintz et al. (1966) have reported a decreasing frequency of errors across all succeeding ordinal positions of the ratio for pigeons on matching-to-sample. Nevin (1967) reported a similar finding for pigeons on simultaneous discrimination. When the total errors across all ordinal positions are examined for the large error producing subjects; S1, S3, S4, S5, S7, and S8 (Appendix C) little error patterning occurred. But if the win-stay, lose-shift errors are examined for each subject for most experimental conditions, it can be seen that error patterns are present that are similar to those reported in the literature. The reason that this error patterning was not reflected in the total errors across all ordinal positions was that win-shift, lose-shift errors had an averaging effect on the total errors which destroyed the error patterns. The deleterious effect of win-shift, lose-shift errors on error patterning is readily evident from the tables in Appendix C. The selective placement of the choice stimuli is one possible explanation for the high frequencies of win-shift, lose-shift error (Appendix B).

The effect of individual experimental conditions on error patterns was minimal. The stimulus sequencing effects of both the external and internal experimental conditions failed to produce systematic changes in error patterns. At best the internal conditions produced the largest effects. Condition G the internal "shift" condition tended to produce more robust standard error patterns. Condition F the internal "stay" condition tended to produce reversed error patterns or no error patterns at all. Neither of these effects were consistent for all subjects across all experimental conditions.

Response Strategies

The sensitivity of response strategies to selective reinforcement was an important question of this study. The selective biasing of the S+ presentation to produce more reinforcement for particular response strategies was not highly successful. Most subjects favored either win-stay or win-shift and lose-stay or lose-shift errors irrespective of experimental conditions. By favoring an error, it is meant that the subject maintained a type of two-trial definition error above the 50% frequency level for all experimental conditions. For example, the least accurate child and pigeon subjects on matching-to-sample favored win-shift errors above win-stay errors generally across experimental conditions. The most accurate child subject and pigeons on simultaneous discrimination favored win-stay errors above win-shift errors, generally across experimental conditions. The robustness of two-trial definition errors was so strong that only on six occasions for all the experimental conditions for all the subjects in Experiments I and II did the occurrence of a favored error fall below 50%. Once an error type was favored, win-shift versus win-stay and lose-shift versus lose-stay, it was maintained over sessions and it was highly resistant to selective reinforcement.

The resistance of response strategies to reinforcement corroborates earlier research findings. Schusterman (1964) found that in a two-choice situation in which either side was reinforced 100% of the trials that selective response strategies developed depending on the age of the subject. Three-year-old children tended to perseverate on one side; 5-year-old children alternated; and 10-year-old children showed no response tendency. This result suggests that response strategies are developmentally based since any response strategy produced 100% reinforcement in this study.

A similar study was performed by Craig and Myers (1963) using a two-choice situation. In this experiment the ratio of reinforcement was not 100% on each side but 60:40 for one group and 80:20 for another group. Kindergarteners, fourth graders, and eighth graders served as subjects. In this study a perseveration strategy on the richer side would be optimal. The 5-year-olds alternated following both reward and nonreward and consistently undermatched. The older children alternated less and then usually after a nonreward trial. This study also provides evidence for a developmental age base for alternation in young subjects.

As the two above studies indicate, children close to 5 years of age tend to alternate in two-choice situations. All child subjects except one in the present research study fell into the 5- and 6-year-old category. The less accurate subjects in this age category had high proportions of win-shift and lose-shift errors. The high frequencies of win-shift and lose-shift errors may thus be a function of the age of the subject.

If accuracy of responding had nothing to do with response strategies, one would expect equal proportions of the four two-trial definition errors for accurate and inaccurate subjects. Gerjuoy and Winters (1968) have shown that accuracy and response strategies have a clear relationship. Gerjuoy and Winters conducted a two-choice, five-task study. The degree of difficulty of solving the number problems varied across the five tasks. Normal and retarded children ranging in ages from the fourth grade to the eighth grade served as subjects. They found that among the nonsolving subjects, as the difficulty of the problem increased the frequency of alternation errors increased. Gerjuoy and Winters included:

> These results led to the inference that in a soluable task with several levels of difficulty more Ss will exhibit alternation as the task becomes more difficult; if the task becomes easier, fewer Ss will alternate above chance. (p. 59)

The matching-to-sample task which is a more complex and difficult discrimination to form than a simultaneous discrimination task should then lead to more alternation or win-shift and lose-shift behavior. This is one possible explanation for the high proportions of win-shift and lose-shift behavior in the matching-to-sample pigeons and the low proportions in the pigeons and some children on simultaneous discrimination.

Schultz (1964) has mentioned four conditions which may facilitate alternation behavior in multi-choice situations: "(1) neither reinforcement information nor knowledge of results, (2) dissimilarity between the choice stimuli, (3) a short intertrial interval, and (4) prior exercise on one alternative." The first two conditions may be accepted as indicators of complex discrimination tasks. The fourth condition is nonapplicable to the present research because the amount of exercise on any one alternative was equated for all subjects in this study. What is important is the length of the intertrial interval. Iwahara (1959) found that spontaneous alternation in a key-pressing, two-choice game decreased as the intertrial interval increased from 0 to 30 seconds. The present research employed a procedure which utilized a 0-second intertrial interval, thus possibly increasing the frequency of win-shift and lose-shift type errors.

The high proportions of win-shift and lose-shift errors and their resistance to reinforcement contingencies lead to a number of conclusions. First, win-shift and lose-shift errors seem to have a strong developmental base for 5 and 6 year olds. Second, the complexity of a discrimination seems to be related to win-shift and lose-shift errors. A more complex matching-to-sample procedure produces more win-shift and lose-shift errors than a simpler procedure such as a simultaneous discrimination. Third, very short inter-trial intervals may produce more win-shift and lose-shift errors.

Internal conditions (B, C, D, and E) and external conditions (F and G) can be compared for their effects on error production, especially for the two-trial definition errors. The question in point is: Does the selective sequencing of stimuli (internally or externally) decrease or increase the proportions of different types of response strategies? It must be kept in mind that the differences in response strategy proportions caused by experimental conditions would be relatively small because of the favoring of one major type of error across all experimental conditions. Even though the differences in proportions may be small the comparisons can still be made.

One would expect an alternating sequence of the S+, either internally or externally, to increase the proportions of win-stay and lose-stay errors and to decrease the proportions of win-shift and lose-shift errors. This is because the alternating of the S+ would by definition reinforce a single-alternation shift in response and not reinforce a position perseveration response. Conversely, one would expect a perseverating sequencing of the S+, either internally or externally, to increase the proportion of win-shift and lose-shift errors and decrease the proportions of win-stay and lose-stay errors.

Seven out of 10 subjects experienced both the internal conditions F (stay) and G (shift). For win-stay and win-shift errors five of the seven subjects showed: (1) a larger proportion of win-shift errors for condition F (stay) than condition G (shift) and (2) a larger proportion of win-stay errors for condition G (shift) than condition F (stay). The average proportion difference between win-stay and win-shift errors for conditions F and G was 24% for the five subjects. For the lose-stay and lose-shift errors six of the seven subjects had: (1) a larger proportion of lose-shift errors for condition F (stay) than condition G (shift) and a larger proportion of lose-stay errors for condition G (shift) than condition F (stay). The seventh subject had equal proportions of lose-shift and lose-stay errors for conditions F and G. The average proportion difference between lose-shift and lose-stay errors for conditions F and G was 27% for the six subjects.

It is clear that the internal sequence conditions had an effect on response strategies. The external conditions did not produce such a clear and constant effect over species and discrimination paradigms. Nor was there a magnitude effect due to parameter differences between the four external conditions. One possible reason that internal conditions produced an effect on response strategies and external conditions did not is that internal conditions contained more trials to produce the desired behavioral change. For example, if a subject does not make mistakes an FR6 contains five internally defined trials leading up to reinforcement and only one externally defined trial followed by reinforcement. The last external trial has the added effect of being followed immediately by reinforcement, but as the data indicate this did not consistently change response strategy proportions for external conditions.

Latencies

In the present experiments, the latency data for children and pigeons in both discrimination paradigms showed a general pattern over ordinal positions of the FR. The longest latencies usually occurred immediately after reinforcement and decreased over succeeding ordinal positions. Mintz et al. (1968) have suggested that for matching-to-sample there are two classes of errors which are differentiated by latency times. One class which is most frequent in number occurs at the beginning of the FR and is characterized by relatively long latencies. These errors according to Mintz et al. may be caused by a self-imposed delay or weak stimulus control. They may in fact be a form of adjunctive behavior. The second class of errors are relatively infrequent and are characterized by shorter latencies in the final steps of the FR. Mintz et al. have suggested that these errors of "excessive haste" may be controlled by the inertia of a response chain leading to the matching response.

The matching response latencies for children and pigeons in the present research corroborate Mintz et al.'s (1968) earlier findings. The present study includes a more indepth analysis of response latencies than the Mintz et al. study by defining two response latencies, a comparison response latency and a sample response latency. Mintz et al. defined only one response latency, the time from the response on the center key to the response on either side key.

Both the comparison response and sample response latencies for children on matching-to-sample showed longer latencies immediately after reinforcement and shorter latencies in the other ordinal positions. The overall differences between response and sample response latencies were different for pigeons and children on matching-to-sample. Since the experimental conditions were held constant for both children and pigeons, this difference possibly reflects a species difference.

The simultaneous discrimination children and pigeon subjects showed the same general latency pattern as the children and pigeons on matching-to-sample. They exhibited longer latencies immediately after reinforcement with shorter latencies in the other ordinal positions of the ratio. Mintz et al.'s (1968) two classes of errors and the behavioral explanations of those errors seems to fit the current simultaneous discrimination data.

No systematic differences were found between correct and error response latencies for any class of subject for any discrimination paradigm in this study. Some repeated acquisition data (Eckerman, 1972) show that latencies for correct responses tend to be longer than the latencies for error responses. But the latencies reported in this research were produced by steady-state responding and not acquisition. Nevin (1967) has reported no systematic differences between correct and error response latencies for asympotic performance of pigeons on simultaneous discrimination. Nevin's findings are replicated by the results reported here for the latency data of children and pigeons on simultaneous discrimination and matching-to-sample.

Summary

1. Error patterns with larger proportions of errors in the first half of the ratio than in the last half of the ratio were found for total errors for pooled data in all experimental groups except pigeons on simultaneous discrimination.

2. A majority of standard error patterns were found for the less accurate individual subjects when total errors were separated into error types.

3. Win-shift, lose-shift errors were found to be the most frequent types of error for the less accurate subjects. This type of error was not correlated with any type of specific error pattern.

4. The most accurate subjects tended to show a majority of reversed error patterns across experimental conditions. These subjects made few win-shift, lose-shift errors and more win-stay, lose-shift and win-stay, lose-stay errors.

5. If a subject's responding was accurate and the number of errors very small, then no error patterning or only weak error patterning occurred.

6. A two-trial error analysis indicated that most subjects showed a favored type of error, either a win-shift or win-stay and lose-shift or lose-stay error across experimental conditions. In general, the less accurate subjects showed preferences for win-shift and lose-shift errors, and the more accurate subjects showed a preference for win-stay errors. The preference for the win-shift and lose-shift (alternation errors) was possibly caused by using a short intertrial interval, complexity of the discrimination, accuracy of the subject, and the developmental age of the subject.

7. Selective reinforcement of particular response strategies produced only small effects for the internal conditions.

8. Latencies for comparison and sample responses of the matching-to-sample subjects and of the responses for the simultaneous discrimination subjects were divided into two classes. The first class included long latency responses occurring immediately after reinforcement. The second class included shorter latencies in the succeeding ordinal positions of the ratio.

9. No consistent latency differences were found between correct and error response latencies for child or pigeon subjects for any discrimination paradigm used in this study.

Proposed Research

One of the important findings of this research was that high frequencies of win-shift, lose-shift errors mask standard error patterns for total errors.

The standard error pattern became evident for a number of subjects when total errors were separated into error types. Studies which systematically controlled win-shift, lose-shift errors by independent parameter manipulation could produce clearer error patterns for total errors. Also the use of a high speed computer which could on-line program the placement of stimuli using antecedent response information could selectively reinforce strategies and possibly manipulate error patterns.

The following recommendations are made to control the high frequency of win-shift, lose-shift errors exhibited by subjects and selectively reinforce response strategies.

1. A discrete trial procedure which utilizes intertrial intervals greater than 0 and up to 30 seconds.

2. Children extending over a wide range of ages should be used.

3. FR and VR schedules of reinforcement should be used in which errors count toward the ratio requirement. If Schultz (1964) is correct in assuming that lack of reinforcement information facilitates alternation errors, an FR schedule which is cyclic should produce fewer win-shift, lose-shift errors than a noncyclic VR schedule. A high frequency of win-shift, lose-shift errors in variable schedules is a possible reason that Davidson and Osborne (1974) did not find error patterning with VR and VI schedules of reinforcement.

4. Two discrimination paradigms differing in complexity should be used such as matching-to-sample and simultaneous discrimination. The less

complex discrimination paradigm would increase accuracy and decrease win-shift, lose-shift errors.

The following recommendations are made to effectively utilize a high speed computer to on-line program stimuli to selectively reinforce response strategies and thus manipulate error patterns.

1. Two response strategies, win-stay, lose-shift and win-shift, lose-stay, should be selectively reinforced. It is expected that a procedure which could effectively reinforce the win-stay, lose-shift strategy would produce good standard error patterns.

2. The response information on a preceeding trial (N-1) should be used to selectively program stimuli on a current trial (N). The on-line programming of stimuli would selectively reinforce a strategy by reducing the subject's response cost in obtaining a reinforcement if that particular response strategy is used by the subject.

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APPENDIXES

Appendix A: Error Patterning for Individual Subjects

Error Patterns for Matching-to-Sample Children

Table 4 contains the error frequencies and percentages for the first and last half of the ratios for each experimental condition for subject S1. When the total errors for each experimental condition are examined, it can be seen that all of the experimental conditions except one (condition C) produced larger percentages of first half ratio errors than last half ratio errors. None of the percentages for total errors was large enough to meet the definition of a standard error pattern. For win-stay, lose-shift errors; conditions B and D produced standard error patterns with 67% and 70% first half ratio errors. Condition F produced a reversed error pattern with 71% last half ratio errors, but the overall error frequencies for this experimental condition were low. Win-shift, lose-stay errors exhibited standard error patterns for conditions D (63% first half errors) and F (62% first half errors) with no reversed error patterns produced. Win-stay, lose-stay errors produced a standard error pattern for only one experimental condition, condition A with 71% first half errors, and no reversed error patterning. Win shift, lose-shift errors produced few error patterns for experimental conditions. Condition C exhibited a reversed pattern for this type of error.

The error frequencies and percentages by halves of the ratio for each experimental condition for S2 are presented in Table 5. For total errors, condition F produced a reversed error pattern with 72% of the errors occurring in the last half of the ratio. Condition G produced a standard error pattern with 65% of the errors occurring in the first half of the ratio.

Table 4

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S1

	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
First Half	105	54	82	56	79	49	65	56	-	-	57	51	-	-
Second Half	89	46	64	44	81	51	52	44	-	-	55	49	-	-
	Win-Stay, Lose-Shift Errors													
First Half	28	57	29[a]	67	13	50	7	70	-	-	2	29[b]	-	-
Second Half	21	43	14	33	13	50	3	30	-	-	5	71	-	-
	Win-Shift, Lose-Stay Errors													
First Half	33	53	22	52	34	57	31[a]	63	-	-	10[a]	62	-	-
Second Half	29	47	20	48	24	43	18	37	-	-	6	38	-	-
	Win-Stay, Lose-Stay Errors													
First Half	17[a]	71	3	50	5	49	5	50	-	-	0	0	-	-
Second Half	7	29	3	50	6	51	5	50	-	-	0	0	-	-
	Win-Shift, Lose-Shift Errors													
First Half	27	46	28	51	27	42[b]	22	46	-	-	45	45	-	-
Second Half	32	54	27	49	38	58	26	54	-	-	54	55	-	-

[a]Standard error pattern.

[b]Reversed error pattern.

Table 5

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S2

	Experimental Conditions													
	A		B		C		D		E		F		G	
		%		%		%		%		%		%		%
Total Errors														
First Half	8	57	–	–	–	–	–	–	62	46	21[b]	28	13	65
Second Half	6	43	–	–	–	–	–	–	72	54	53	72	7	35
Win-Stay, Lose-Shift Errors														
First Half	6[a]	75	–	–	–	–	–	–	19	50	12[b]	41	3[a]	60
Second Half	2	25	–	–	–	–	–	–	19	50	17[b]	59	2	40
Win-Shift, Lose-Stay Errors														
First Half	1[b]	33	–	–	–	–	–	–	2[b]	40	0[b]	0	6[a]	86
Second Half	2	67	–	–	–	–	–	–	3	60	1	100	1	14
Win-Stay, Lose-Stay Errors														
First Half	1[b]	100	–	–	–	–	–	–	34[b]	41	8[b]	20	4	50
Second Half	0	0	–	–	–	–	–	–	49	59	33	80	4	50
Win-Shift, Lose-Shift Errors														
First Half	0[b]	0	–	–	–	–	–	–	7[a]	87	1[b]	33	0	0
Second Half	2	100	–	–	–	–	–	–	1	13	2	67	0	0

[a] Standard error pattern.

[b] Reversed error pattern.

Win-stay, lose-shift errors exhibited standard error patterns for conditions A and G with larger percentages of first half errors (75% and 60%). Condition F produced a reversed error pattern with 59% last half ratio errors. Win-shift, lose-stay errors exhibited reversed error patterns for conditions A, E, and F and a standard error pattern for condition G, but the overall frequencies for this type of error were very low. Win-stay, lose-stay were distributed in reversed patterns for all experimental conditions except condition G. Condition A had very low frequencies of errors, but conditions E and F showed high frequencies of win-stay, lose-stay errors. Win-shift, lose-shift errors showed reversed error patterning for conditions A and F and standard error patterning for condition E, but again the relative frequencies of errors were low.

From Table 6 for subject S3 it can be seen that all the experimental conditions produced larger percentages of first half than last half ratio errors. But only conditions B and G meet the standard error patterns across all experimental conditions with high frequencies of errors. Win-shift, lose-stay produced standard error patterns for conditions A, B, D, and G with condition F producing a reversed error pattern. The overall frequencies of the win-shift, lose-stay errors were low with a one error difference between the first and last half of the ratio for conditions D and F. Win-stay, lose-stay errors showed standard error patterning for conditions B, C, D, and F but the overall error frequencies were very low. The most frequent type of

Table 6

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S3

	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
First Half	130	57	124[a]	58	104	57	93	53	-	-	97	51	134[a]	61
Second Half	98	43	91	42	78	43	82	47	-	-	92	49	84	39
	Win-Stay, Lose-Shift Errors													
First Half	40[a]	61	41[a]	66	30[a]	71	32[a]	67	-	-	16[a]	70	61[a]	75
Second Half	25	39	21	34	12	29	16	33	-	-	7	30	20	25
	Win-Shift, Lose-Stay Errors													
First Half	12[a]	75	4[a]	67	5	42	2[a]	67	-	-	2[b]	40	3[a]	100
Second Half	4	25	2	33	7	58	1	33	-	-	3	60	0	0
	Win-Stay, Lose-Stay Errors													
First Half	21	50	4[a]	75	1[a]	100	2[a]	100	-	-	1[a]	100	1	50
Second Half	20	50	1	25	0	0	0	0	-	-	0	0	1	50
	Win-Shift, Lose-Shift Errors													
First Half	56	54	73	53	67	52	56	46	-	-	77	49	67	52
Second Half	48	46	65	47	58	48	64	53	-	-	81	51	61	48

[a]Standard error pattern.
[b]Reversed error pattern.

error was win-shift, lose-shift errors which exhibited no error patterning for any of the experimental conditions.

Error Patterns for Simultaneous-Discrimination Children

Error frequencies and percentages for each half of the ratio by experimental condition for subject S4 are given in Table 7. For total errors, it can be seen that each experimental condition produced more first half ratio errors that last half ratio errors. Only conditions F and G meet the definition of a standard error pattern for the total errors. For the win-stay, lose-shift error analysis, all experimental conditions produced more first half ratio errors with relatively high frequencies of errors. Standard error patterning was exhibited for only conditions F and G for win-stay, lose-shift errors. The win-shift, lose-shift errors produced a reduced frequency of errors with reversed error patterning for conditions C and F and a standard error pattern for condition G. Win-stay, lose-stay errors produced good error frequencies for conditions A and G with no error patterning. Condition F met the reversed error patterning definition, but this pattern was represented by only one error. Win-shift, lose-shift errors were the most frequent type of error for each experimental condition except condition G. Condition G represented a large frequency decrease for win-shift, lose-shift errors. Although all experimental conditions produced more first half errors only condition F met the standard error pattern definition.

Table 7

Error Frequencies and Percentages by Halves of the Fixed Ratio for Subject S4

	Experimental Conditions													
	A	%	B	%	C	%	D	%	E	%	F	%	G	%
Total Errors														
First Half	234	52	–	–	248	52	–	–	–	–	156[a]	58	115[a]	60
Second Half	218	48	–	–	228	48	–	–	–	–	115	42	80	40
Win-Stay, Lose-Shift Errors														
First Half	88	54	–	–	85	54	–	–	–	–	22[a]	59	38[a]	63
Second Half	74	46	–	–	73	46	–	–	–	–	16	41	22	37
Win-Shift, Lose-Stay Errors														
First Half	17	50	–	–	2[b]	33	–	–	–	–	3[b]	38	19[a]	79
Second Half	16	50	–	–	4	67	–	–	–	–	5	62	5	21
Win-Stay, Lose-Stay Errors														
First Half	21	45	–	–	2	50	–	–	–	–	0[b]	0	29	50
Second Half	26	55	–	–	2	50	–	–	–	–	1	100	31	50
Win-Shift, Lose-Shift Errors														
First Half	109	52	–	–	159	52	–	–	–	–	131[a]	58	29	57
Second Half	102	48	–	–	149	48	–	–	–	–	93	42	22	43

[a] Standard error pattern.
[b] Reversed error pattern.

The error frequencies and percentages for S5 for first and last half ratio errors are presented in Table 8. For total errors, each experimental condition except condition G had a larger percentage of first half ratio errors than last half ratio errors. None of the experimental conditions except condition G met the error pattern definition. Condition G exhibited a reversed error pattern with 79% last half errors. Win-stay, lose-shift errors produced standard error patterns for conditions A, C, and F with relatively high frequencies of errors. Condition G produced a reversed error pattern for win-stay, lose-shift errors with the lowest frequency of any experimental condition for win-stay, lose-shift errors. Win-shift, lose-stay errors exhibited lower error frequencies with standard error patterning for conditions A, C, and D and a reversed error pattern for condition G. Win-stay, lose-stay errors showed the lowest frequencies of errors with standard error patterning for conditions D, F, and G. Win-shift, lose-shift errors were the more frequent type of error for every experimental condition except condition G. Condition G exhibited a dramatic lowering in error frequency and a good reversed error pattern. The other experimental conditions showed no error patterns.

Table 9 presented the error frequencies and percentages for each half of the ratio for S6. Total errors for conditions E and F exhibited standard error patterns while condition G exhibited a reversed error pattern. Win-stay, lose-shift errors were the most frequent type of error across most experimental conditions. For the win-stay, lose-shift errors conditions B and G showed reversed error patterns and condition F showed a standard error

Table 8

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S5

	Experimental Conditions													
	A		B		C		D		E		F		G	
					Total Errors									
		%		%		%		%		%		%		%
First Half	266	55	–	–	242	52	244	53	–	–	229	51	6[b]	21
Second Half	216	45	–	–	226	48	216	47	–	–	216	49	23	79
					Win-Stay, Lose-Shift Errors									
First Half	93[a]	59	–	–	82[a]	57	86	51	–	–	41[a]	67	0[b]	0
Second Half	64	41	–	–	68	42	82	49	–	–	20	33	10	100
					Win-Shift, Lose-Stay Errors									
First Half	18[a]	64	–	–	18[a]	66	12[a]	75	–	–	22	46	0[b]	0
Second Half	10	36	–	–	9	34	4	25	–	–	26	54	3	100
					Win-Stay, Lose-Stay Errors									
First Half	5	50	–	–	8	50	12[a]	.63	–	–	14[a]	82	5[a]	62
Second Half	5	50	–	–	9	50	7	37	–	–	3	18	3	38
					Win-Shift, Lose-Shift Errors									
First Half	150	52	–	–	134	49	134	52	–	–	152	48	1[b]	13
Second Half	137	48	–	–	140	51	123	48	–	–	167	52	7	87

[a] Standard error pattern.
[b] Reversed error pattern.

Table 9

Error Frequencies and Percentages by Halves of the Fixed Ratio for Subject S6

	Experimental Conditions													
	A		B		C		D		E		F		G	
Total Errors														
		%		%		%		%		%		%		%
First Half	12	55	18	43	25	50	24	43	31[a]	60	15[a]	68	8[b]	26
Second Half	10	45	24	57	25	50	32	57	20	40	7	32	23	74
Win-Stay, Lose-Shift Errors														
First Half	9	50	8[b]	32	14	45	16	44	16	50	9[a]	69	1[b]	20
Second Half	10	50	17	68	17	55	20	56	15	50	4	31	4	80
Win-Shift, Lose-Stay Errors														
First Half	0	0	3[a]	75	5[a]	62	2[b]	40	2[a]	67	0	0	4	44
Second Half	0	0	1	25	3	38	3	60	1	33	0	0	5	56
Win-Stay, Lose-Stay Errors														
First Half	1[a]	100	2[b]	40	3	50	2[b]	40	9[a]	82	1[a]	100	3[b]	23
Second Half	0	0	3	60	3	50	3	60	2	18	0	0	10	77
Win-Shift, Lose-Shift Errors														
First Half	2[a]	100	5[a]	71	3[a]	60	3	43	3[a]	75	4[a]	67	0[b]	0
Second Half	0	0	2	29	2	40	4	57	1	25	2	23	4	100

[a]Standard error pattern.
[b]Reversed error pattern.

pattern. Win-shift, lose-shift errors were low in frequency and showed standard error patterns for conditions B, C, and E and a reversed error pattern for condition D. The differences between first and last half errors which differentiated these error patterns were small in that none exceeded two errors. Win-stay, lose-stay errors showed standard error patterns for conditions A, E, and F and reversed error patterns for B and G. The overall error frequencies were good for conditions E and G but very small for conditions A, B, D, and F. Win-shift, lose-shift errors had low error frequencies across experimental conditions. Conditions A, B, C, E, and F showed standard error patterns with condition G showing a reversed error pattern.

Error Patterns for Matching-to-Sample Pigeons

Table 10 contains the error frequencies and percentages by halves of the ratio for S7. Total errors exhibited no error patterns for any of the experimental conditions. Win-stay, lose-shift errors showed standard error patterning for experimental condition F, but no patterning for conditions A and D. Win-shift lose-stay errors showed standard error patterning for all three experimental conditions while win-stay, lose-stay errors showed standard error patterning for conditions D and F. Win-shift, lose-shift errors showed more last half ratio errors than first half ratio errors, but only conditions A and D meet the reversed error patterning definition. The win-shift, lose-shift errors were clearly the most frequent type of error for all experimental conditions.

Table 10

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S7

	Experimental Conditions													
	A		B		C		D		E		F		G	
Total Errors		%		%		%		%		%		%		%
First Half	178	46	–	–	–	–	216	51	–	–	207	57	–	–
Second Half	210	54	–	–	–	–	206	49	–	–	165	43	–	–
Win-Stay, Lose-Shift Errors														
First Half	55	48	–	–	–	–	77	57	–	–	40[a]	70	–	–
Second Half	59	52	–	–	–	–	59	43	–	–	17	30	–	–
Win-Shift, Lose-Stay Errors														
First Half	32[a]	63	–	–	–	–	39[a]	60	–	–	47[a]	68	–	–
Second Half	19	37	–	–	–	–	26	40	–	–	22	32	–	–
Win-Stay, Lose-Stay Errors														
First Half	32	57	–	–	–	–	36[a]	73	–	–	29[a]	85	–	–
Second Half	24	43	–	–	–	–	13	27	–	–	6	15	–	–
Win-Shift, Lose-Shift Errors														
First Half	59[b]	35	–	–	–	–	64[b]	37	–	–	91	43	–	–
Second Half	108	65	–	–	–	–	108	63	–	–	120	57	–	–

[a] Standard error pattern.
[b] Reversed error pattern.

Error frequencies and percentages by halves of the ratio are presented in Table 11 for S8. Total errors showed a standard error pattern for condition G only. Conditions A and E had approximately equal percentages of errors in the first and last halves of the ratio. Win-stay, lose-shift errors were similar to the total error patterning with only condition G exhibiting a standard error pattern. Win-shift, lose-stay errors and win-stay, lose-stay errors both showed standard error patterning for all experimental conditions. Win-shift, lose-shift errors exhibited a reversed error patterning for experimental conditions A and E.

Error Patterns for Simultaneous-Discrimination Pigeons

Error frequencies and percentages by halves of the ratio and by experimental condition are presented in Table 12 for S9. For total errors, conditions F and G produced standard error patterns while condition D produced a reversed error pattern. Win-stay, lose-shift errors exhibited a reversed error pattern for condition G. The overall error frequencies for win-stay, lose-shift errors was very low with condition F having no win-stay, lose-shift errors. Win-shift, lose-stay errors also had very low error frequencies with the differences between first and last half ratio errors being small. Conditions F and G produced standard error patterning, and condition D produced a reversed error pattern. Win-stay, lose-stay errors were the most frequent error type across all experimental conditions. Condition D produced a reversed error pattern while conditions F and G produced standard

Table 11

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S8

	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
First Half	208	47	-	-	-	-	-	-	205	49	-	-	270	63
Second Half	231	53	-	-	-	-	-	-	214	51	-	-	159	27
	Win-Stay, Lose-Shift Errors													
First Half	70	49	-	-	-	-	-	-	73	52	-	-	100[a]	65
Second Half	74	51	-	-	-	-	-	-	68	48	-	-	54	35
	Win-Shift, Lose-Stay Errors													
First Half	26[a]	68	-	-	-	-	-	-	38[a]	86	-	-	27[a]	90
Second Half	12	32	-	-	-	-	-	-	6	14	-	-	3	10
	Win-Stay, Lose-Stay Errors													
First Half	30[a]	83	-	-	-	-	-	-	14[a]	82	-	-	48[a]	79
Second Half	6	17	-	-	-	-	-	-	3	18	-	-	13	21
	Win-Shift, Lose-Shift Errors													
First Half	82[b]	37	-	-	-	-	-	-	80[b]	37	-	-	95	52
Second Half	139	63	-	-	-	-	-	-	137	63	-	-	89	48

[a]Standard error pattern.
[b]Reversed error pattern.

Table 12

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S9

	A		B		C		D		E		F		G	
		%		%		%		%		%		%		%
Total Errors														
First Half	0	0	–	–	–	–	5[b]	29	–	–	7[a]	100	22[a]	96
Second Half	0	0	–	–	–	–	12	71	–	–	0	0	1	04
Win-Stay, Lose-Shift Errors														
First Half	0	0	–	–	–	–	0[b]	0	–	–	0	0	2[a]	100
Second Half	0	0	–	–	–	–	4	100	–	–	0	0	0	0
Win-Shift, Lose-Stay Errors														
First Half	0	0	–	–	–	–	0[b]	0	–	–	1[a]	100	6[a]	100
Second Half	0	0	–	–	–	–	2	100	–	–	0	0	0	0
Win-Stay, Lose-Stay Errors														
First Half	0	0	–	–	–	–	5[b]	42	–	–	5[a]	100	14[a]	93
Second Half	0	0	–	–	–	–	7	58	–	–	0	0	1	07
Win-Shift, Lose-Shift Errors														
First Half	0	0	–	–	–	–	0	0	–	–	1[a]	100	0	0
Second Half	0	0	–	–	–	–	0	0	–	–	0	0	0	0

Note: Columns A–G are Experimental Conditions.

[a]Standard error pattern.
[b]Reversed error pattern.

error patterns for this type of error. Win-shift, lose-shift errors in effect did not exist for S9. Only one win-shift, lose-shift error was produced for condition F meeting the standard error pattern definition.

Table 13 contains the error frequencies and percentages by halves of the ratio for experimental conditions for S10. For total errors, conditions A, E, and G exhibited reversed error patterning. All conditions for the win-stay, lose-shift errors produced reversed error patterning. Win-shift, lose-shift errors produced standard error patterning for conditions A and G, but the error frequencies for these conditions were very low. Win-stay, lose-stay errors were the most frequent type of error, and they showed reversed error patterning across all experimental conditions. Win-shift, lose-shift errors were very low in frequency and showed standard error patterning for condition F only.

Table 13

Error Frequencies and Percentages by Halves of

the Fixed Ratio for Subject S10

	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
First Half	22[b]	28	-	-	-	-	-	-	9[b]	26	12	46	24[b]	24
Second Half	56	72	-	-	-	-	-	-	26	74	14	54	74	76
	Win-Stay, Lose-Shift Errors													
First Half	14[b]	27	-	-	-	-	-	-	3[b]	18	7[b]	41	4[b]	14
Second Hafl	37	73	-	-	-	-	-	-	14	82	10	59	25	86
	Win-Shift, Lose-Stay Errors													
First Half	1[a]	100	-	-	-	-	-	-	0	0	0	0	3[a]	100
Second Half	0	0	-	-	-	-	-	-	0	0	0	0	0	0
	Win-Stay, Lose-Stay Errors													
First Half	7[b]	27	-	-	-	-	-	-	6[b]	33	2[b]	29	17[b]	.26
Second Half	18	73	-	-	-	-	-	-	12	67	5	71	49	.74
	Win-Shift, Lose-Shift Errors													
First Half	0	0	-	-	-	-	-	-	0	0	3	75	0	0
Second Half	0	0	-	-	-	-	-	-	0	0	1	25	0	0

[a]Standard error pattern.
[b]Reversed error pattern.

Appendix B: S+ Positions for Experimental Conditions

Table 14

Right and Left Position of the S+ for a 30-Trial Sequence for the

External FR Condition 50% Stay and 50% Shift for

Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	R	L	R	L	L
2	L	R	R	L	R
3	R	R	R	R	R
4	L	L	L	R	L
5	L	R	R	R	L
6	R	L	R	L	R
7	R	L	R	R	R
8	L	L	L	R	R
9	L	R	R	L	L
10	R	R	R	R	R
11	R	L	L	R	L
12	L	L	L	R	L
13	R	R	L	L	L
14	R	R	R	L	R
15	R	R	R	R	R
16	L	L	L	L	L
17	L	L	L	L	R
18	R	L	R	R	L
19	L	R	L	L	L
20	L	R	R	L	L
21	R	L	R	R	R
22	R	L	L	R	R
23	R	R	L	L	L
24	L	R	R	L	L
25	L	L	L	L	R
26	L	L	L	R	R
27	R	R	L	L	R
28	R	L	R	L	L
29	L	R	L	R	L
30	L	R	L	R	R

Table 15

Right and Left Position of the S+ for a 30-Trial Sequence for the

External FR Condition 67% Stay and 33% Shift for

Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	R	R	R	L	R
2	R	R	L	R	L
3	R	R	L	R	L
4	L	R	R	L	L
5	R	L	R	L	L
6	R	R	R	R	L
7	R	L	R	R	L
8	L	L	R	L	R
9	L	R	R	R	R
10	L	R	L	L	R
11	L	R	R	L	L
12	R	R	R	L	R
13	R	L	R	L	R
14	L	L	L	L	L
15	R	L	L	L	L
16	L	L	R	L	R
17	L	R	L	R	L
18	R	L	L	R	L
19	R	L	L	R	L
20	R	L	L	R	L
21	R	L	L	R	L
22	R	L	L	R	R
23	L	L	L	R	R
24	L	R	L	L	R
25	L	R	R	L	R
26	L	L	L	L	L
27	L	L	L	R	R
28	L	R	R	R	R
29	L	R	R	R	R
30	R	R	R	L	R

Table 16

Right and Left Position of the S+ for a 30-Trial Sequence for the External FR Condition 33% Stay and 67% Shift for Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	L	L	R	R	L
2	R	R	L	L	L
3	R	L	R	L	L
4	L	R	R	L	R
5	L	R	L	R	R
6	R	L	R	R	L
7	L	R	L	L	R
8	L	L	L	R	R
9	R	L	L	L	L
10	R	R	R	L	R
11	L	L	L	R	L
12	L	L	R	R	R
13	R	R	R	L	R
14	L	L	L	L	L
15	R	L	R	R	R
16	L	R	R	L	L
17	R	R	L	R	L
18	L	R	R	L	R
19	R	L	L	R	L
20	R	R	L	L	L
21	R	R	R	R	R
22	L	L	R	R	R
23	L	R	L	R	L
24	R	R	R	L	R
25	L	L	R	R	L
26	R	L	L	R	L
27	L	L	L	L	R
28	L	R	R	L	R
29	R	L	L	R	L
30	R	R	L	L	R

Table 17

Right and Left Position of the S+ for a 30-Trial Sequence for the External FR Condition 90% Stay and 10% Shift for Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	L	L	L	R	R
2	L	L	L	R	R
3	L	L	L	R	R
4	R	L	L	R	L
5	R	L	L	R	L
6	R	L	L	L	L
7	R	R	R	L	L
8	R	R	R	L	L
9	R	R	R	L	L
10	R	R	R	L	R
11	R	R	R	L	R
12	R	R	R	L	R
13	R	R	L	L	R
14	R	R	L	L	L
15	R	R	L	L	L
16	L	R	L	R	L
17	L	L	L	R	L
18	L	L	L	R	L
19	L	L	L	R	L
20	L	L	L	R	L
21	R	L	L	R	L
22	R	R	L	R	L
23	R	R	L	R	L
24	R	R	L	L	L
25	R	R	R	L	L
26	R	R	R	L	L
27	R	R	R	L	L
28	R	R	R	L	L
29	R	R	R	L	L
30	R	R	R	L	L

Table 18

Right and Left Position of the S+ for a 30-Trial Sequence for the

External FR Condition 10% Stay and 90% Shift for

Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	L	L	L	R	R
2	R	R	R	L	L
3	L	L	L	R	R
4	L	R	R	L	L
5	R	L	L	L	R
6	L	R	L	R	L
7	R	L	R	L	R
8	L	R	L	R	L
9	R	L	L	L	R
10	L	R	R	R	L
11	R	L	L	L	R
12	R	R	R	R	L
13	L	L	L	L	R
14	R	L	R	L	L
15	L	R	L	R	L
16	R	R	R	L	R
17	L	L	L	R	L
18	R	R	R	R	R
19	L	L	R	L	L
20	R	R	L	R	R
21	L	L	R	L	R
22	R	R	L	R	L
23	L	L	R	L	R
24	L	R	L	R	L
25	R	L	R	L	R
26	L	L	L	R	R
27	R	R	R	L	L
28	L	L	L	R	R
29	R	R	R	L	L
30	L	L	L	R	R

Table 19

Right and Left Position of the S+ for a 30-Trial Sequence for the

Internal FR Condition 50% Stay and 50% Shift for

Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	R	L	R	R	L
2	R	L	R	L	R
3	L	L	R	L	L
4	L	R	L	R	R
5	R	R	L	L	R
6	R	L	R	L	L
7	L	R	R	R	L
8	L	R	L	R	L
9	L	L	L	R	R
10	R	R	R	L	R
11	R	R	R	R	R
12	L	L	R	R	L
13	L	L	L	L	L
14	L	R	L	L	R
15	R	L	R	R	R
16	L	L	R	R	R
17	R	R	L	R	L
18	R	R	L	L	L
19	R	R	L	L	R
20	L	L	R	R	R
21	L	L	L	R	L
22	R	R	L	L	L
23	R	R	R	L	R
24	L	L	R	L	R
25	R	L	L	R	L
26	R	R	L	R	L
27	L	R	R	L	R
28	L	R	L	L	R
29	L	L	L	L	L
30	R	L	R	R	L

Table 20

Right and Left Position of the S+ for a 30-Trial Sequence for the Internal FR Condition 10% Stay and 90% Shift for Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	L	L	R	R	L
2	R	R	L	L	R
3	L	L	R	L	L
4	L	R	L	R	R
5	R	L	L	L	L
6	L	R	R	R	R
7	R	L	L	L	L
8	L	R	R	R	R
9	R	L	L	R	R
10	L	R	R	L	L
11	L	L	L	R	R
12	R	R	R	L	L
13	L	L	L	R	R
14	R	R	L	L	L
15	L	R	R	R	R
16	L	L	L	L	R
17	R	R	R	L	L
18	L	L	L	R	R
19	R	R	R	L	L
20	L	L	L	R	L
21	R	L	R	L	R
22	L	R	R	R	L
23	R	L	L	R	R
24	L	R	R	L	L
25	R	L	L	R	R
26	L	R	R	L	L
27	R	R	L	R	R
28	L	L	R	L	L
29	R	R	L	R	R
30	L	L	R	L	L

Table 21

Right or Left Position of the S+ for a 30-Trial Sequence for the Internal FR Condition 90% Stay and 10% Shift for Five Stimulus Tapes

Trial	Tape 1	Tape 2	Tape 3	Tape 4	Tape 5
1	R	L	R	L	L
2	R	L	R	L	L
3	R	L	R	L	L
4	R	L	R	L	L
5	R	L	R	L	L
6	R	R	R	L	L
7	R	R	R	L	R
8	R	R	R	R	R
9	R	R	R	R	R
10	R	R	R	R	R
11	R	R	R	R	R
12	R	R	R	R	R
13	R	R	R	R	R
14	R	R	L	R	R
15	R	R	L	L	L
16	L	R	L	L	L
17	L	R	L	L	L
18	L	R	L	L	L
19	L	R	L	L	L
20	L	L	L	L	L
21	L	L	R	L	L
22	L	L	R	L	L
23	L	L	R	L	L
24	L	L	L	R	L
25	R	L	L	R	R
26	L	L	L	R	R
27	L	L	L	R	R
28	L	L	L	R	R
29	L	L	L	R	R
30	L	R	L	R	R

Appendix C: Error Frequencies and Percentages by Ordinal Position of the Fixed Ratio for Individual Subjects

Table 22

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S1

Ordinal Position	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
1	37	19	26	18	25	16	16	14	–	–	11	10	–	–
2	32	16	25	17	35	22	31	26	–	–	25	22	–	–
3	36	19	31	21	19	12	18	15	–	–	21	19	–	–
4	35	18	28	20	29	18	16	14	–	–	27	24	–	–
5	29	15	19	13	28	18	14	12	–	–	17	15	–	–
6	25	13	16	11	24	14	22	19	–	–	11	10	–	–
	Win-Stay, Lose-Shift Errors													
1	8	17	6	14	3	12	0	0	–	–	0	0	–	–
2	10	20	12	28	8	31	6	60	–	–	2	29	–	–
3	10	20	11	26	2	08	1	10	–	–	0	0	–	–
4	7	14	7	16	7	30	1	10	–	–	2	29	–	–
5	6	12	5	12	5	19	1	10	–	–	0	0	–	–
6	8	17	2	04	1	04	1	10	–	–	3	42	–	–
	Win-Shift, Lose-Stay Errors													
1	7	11	5	12	6	10	1	02	–	–	1	06	–	–
2	11	18	6	14	18	31	17	35	–	–	5	32	–	–
3	15	24	11	26	10	17	13	27	–	–	4	25	–	–
4	19	31	10	24	9	16	10	20	–	–	5	31	–	–
5	7	11	10	24	12	21	8	16	–	–	1	06	–	–
6	3	05	0	0	3	5	0	0	–	–	0	0	–	–
	Win-Stay, Lose-Stay Errors													
1	10	42	1	17	3	28	1	10	–	–	0	0	–	–
2	4	16	1	17	0	0	3	30	–	–	0	0	–	–
3	3	13	1	17	2	18	1	10	–	–	0	0	–	–
4	2	08	3	50	4	36	3	30	–	–	0	0	–	–
5	3	13	0	0	2	18	2	20	–	–	0	0	–	–
6	2	08	0	0	0	0	0	0	–	–	0	0	–	–
	Win-Shift, Lose-Shift Errors													
1	12	20	14	25	13	20	14	29	–	–	10	11	–	–
2	7	12	6	12	9	14	5	10	–	–	18	18	–	–
3	8	14	8	15	5	08	3	06	–	–	17	17	–	–
4	7	12	9	16	9	14	2	04	–	–	20	20	–	–
5	13	22	4	07	9	14	3	06	–	–	16	16	–	–
6	12	20	14	25	20	30	21	45	–	–	18	18	–	–

Table 23

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S2

Ordinal Position	A		B		C		D		E		F		G	
					Total Errors									
		%		%		%		%		%		%		%
1	3	21	–	–	–	–	–	–	17	13	8	11	7	35
2	3	21	–	–	–	–	–	–	22	16	3	04	2	10
3	2	15	–	–	–	–	–	–	23	17	10	14	4	20
4	0	0	–	–	–	–	–	–	28	21	21	28	3	15
5	4	28	–	–	–	–	–	–	13	10	7	09	3	15
6	2	15	–	–	–	–	–	–	21	23	25	34	1	05
					Win-Stay, Lose-Shift Errors									
1	1	12	–	–	–	–	–	–	5	13	5	17	2	40
2	3	38	–	–	–	–	–	–	6	17	3	10	1	20
3	2	26	–	–	–	–	–	–	8	21	4	15	0	0
4	0	0	–	–	–	–	–	–	7	18	3	10	1	20
5	1	12	–	–	–	–	–	–	2	05	3	10	0	0
6	1	12	–	–	–	–	–	–	10	26	11	38	1	20
					Win-Shift, Lose-Stay Errors									
1	1	33	–	–	–	–	–	–	1	20	0	0	4	58
2	0	0	–	–	–	–	–	–	1	20	0	0	0	0
3	0	0	–	–	–	–	–	–	0	0	0	0	2	28
4	0	0	–	–	–	–	–	–	3	60	0	0	0	0
5	2	67	–	–	–	–	–	–	3	0	1	100	1	14
6	0	0	–	–	–	–	–	–	0	0	0	0	0	0
					Win-Stay, Lose-Stay Errors									
1	1	100	–	–	–	–	–	–	8	10	2	05	1	13
2	0	0	–	–	–	–	–	–	13	16	0	0	1	13
3	0	0	–	–	–	–	–	–	13	16	6	15	2	25
4	0	0	–	–	–	–	–	–	18	22	17	41	2	25
5	0	0	–	–	–	–	–	–	11	13	2	05	2	25
6	0	0	–	–	–	–	–	–	20	23	14	34	0	0
					Win-Shift, Lose-Shift Errors									
1	0	0	–	–	–	–	–	–	3	37	1	33	0	0
2	0	0	–	–	–	–	–	–	2	25	0	0	0	0
3	0	0	–	–	–	–	–	–	2	25	0	0	0	0
4	0	0	–	–	–	–	–	–	0	0	1	33	0	0
5	1	50	–	–	–	–	–	–	0	0	1	33	0	0
6	1	50	–	–	–	–	–	–	1	13	0	0	0	0

Table 24

Error Frequencies and Percentages by Ordinal Position of the Fixed Ratio for Subject S3

Ordinal Position	Experimental Conditions A		B		C		D		E		F		G	
							Total Errors							
		%		%		%		%		%		%		%
1	92	40	79	37	75	41	65	37	-	-	51	27	93	43
2	76	33	89	42	58	32	57	32	-	-	92	49	82	37
3	60	27	46	21	49	27	54	31	-	-	46	24	43	20
							Win-Stay, Lose-Shift Errors							
1	26	39	22	35	20	48	21	43	-	-	10	42	42	51
2	29	44	38	61	20	48	23	47	-	-	13	54	39	48
3	11	17	2	03	2	04	5	10	-	-	1	04	1	01
							Win-Shift, Lose-Stay Errors							
1	10	62	3	43	4	31	2	50	-	-	1	17	3	75
2	4	25	3	43	3	23	1	25	-	-	3	50	1	25
3	2	13	1	14	6	46	1	.25	-	-	2	33	0	0
							Win-Stay, Lose-Stay Errors							
1	16	39	3	50	1	50	2	75	-	-	1	100	0	0
2	10	24	3	50	1	50	1	25	-	-	0	0	3	100
3	15	37	0	0	0	0	0	0	-	-	0	0	0	0
							Win-Shift, Lose-Shift Errors							
1	40	38	51	36	50	40	40	33	-	-	39	25	48	37
2	33	31	45	32	34	27	32	27	-	-	76	48	39	30
3	32	30	43	.31	41	33	48	40	-	-	43	27	42	33

Table 25

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S4

Ordinal Position	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
1	89	20	–	–	83	17	–	–	–	–	31	11	59	30
2	66	15	–	–	59	13	–	–	–	–	67	25	32	17
3	80	17	–	–	106	22	–	–	–	–	58	21	24	12
4	83	18	–	–	86	18	–	–	–	–	48	18	27	14
5	86	19	–	–	99	21	–	–	–	–	41	15	28	14
6	49	11	–	–	43	09	–	–	–	–	26	10	25	13
	Win-Stay, Lose-Shift Errors													
1	26	16	–	–	26	16	–	–	–	–	3	08	20	33
2	31	19	–	–	24	15	–	–	–	–	11	29	11	18
3	31	19	–	–	35	22	–	–	–	–	8	21	7	12
4	33	20	–	–	38	24	–	–	–	–	5	13	8	13
5	30	19	–	–	34	22	–	–	–	–	5	13	5	08
6	11	07	–	–	1	01	–	–	–	–	6	16	9	16
	Win-Shift, Lose-Stay Errors													
1	8	24	–	–	0	0	–	–	–	–	1	13	11	46
2	5	16	–	–	1	17	–	–	–	–	1	13	5	21
3	4	12	–	–	1	17	–	–	–	–	1	13	3	13
4	3	09	–	–	1	17	–	–	–	–	1	13	2	08
5	9	27	–	–	2	32	–	–	–	–	2	25	2	08
6	4	12	–	–	1	17	–	–	–	–	2	25	1	04
	Win-Stay, Lose-Stay Errors													
1	8	17	–	–	0	0	–	–	–	–	0	0	7	12
2	5	11	–	–	1	25	–	–	–	–	0	0	12	20
3	8	17	–	–	1	25	–	–	–	–	0	0	10	17
4	11	23	–	–	1	25	–	–	–	–	1	100	12	20
5	11	23	–	–	1	25	–	–	–	–	0	0	17	28
6	4	09	–	–	0	0	–	–	–	–	0	0	2	03
	Win-Shift, Lose-Shift Errors													
1	47	22	–	–	57	19	–	–	–	–	27	11	21	41
2	25	12	–	–	33	11	–	–	–	–	55	26	4	08
3	37	18	–	–	69	22	–	–	–	–	49	22	4	08
4	36	17	–	–	46	15	–	–	–	–	41	18	5	10
5	36	17	–	–	62	20	–	–	–	–	34	15	4	08
6	30	14	–	–	41	13	–	–	–	–	18	08	13	25

Table 26

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S5

Ordinal Position	Experimental Condition													
	A		B		C		D		E		F		G	
					Total Errors									
		%		%		%		%		%		%		%
1	106	22	–	–	83	18	79	17	–	–	49	11	1	03
2	71	15	–	–	73	15	53	11	–	–	92	21	2	07
3	89	18	–	–	86	19	112	24	–	–	88	20	3	10
4	84	17	–	–	87	19	87	19	–	–	80	18	12	41
5	77	16	–	–	100	21	74	16	–	–	76	17	6	21
6	55	12	–	–	39	09	55	13	–	–	60	13	5	18
					Win-Stay, Lose-Shift Errors									
1	35	22	–	–	27	18	24	14	–	–	16	26	0	0
2	30	19	–	–	26	17	21	13	–	–	10	16	0	0
3	28	18	–	–	29	19	41	24	–	–	15	25	0	0
4	23	21	–	–	32	22	39	23	–	–	11	18	5	50
5	28	18	–	–	36	24	35	21	–	–	5	08	2	20
6	3	02	–	–	0	0	8	05	–	–	4	07	3	30
					Win-Shift, Lose-Stay Errors									
1	7	25	–	–	8	29	2	13	–	–	2	04	0	0
2	4	14	–	–	6	22	4	25	–	–	10	21	0	0
3	7	25	–	–	4	15	6	37	–	–	10	21	0	0
4	5	18	–	–	4	15	1	05	–	–	5	10	2	67
5	2	07	–	–	4	15	1	06	–	–	9	19	1	33
6	3	11	–	–	1	04	2	13	–	–	12	25	0	0
					Win-Stay, Lose-Stay Errors									
1	2	20	–	–	2	12	4	21	–	–	3	18	1	13
2	1	10	–	–	4	24	4	21	–	–	7	40	2	25
3	2	20	–	–	2	12	4	21	–	–	4	24	2	25
4	0	0	–	–	5	28	5	26	–	–	3	18	1	13
5	1	10	–	–	4	24	2	11	–	–	0	0	2	.25
6	4	40	–	–	0	0	0	0	–	–	0	0	0	0
					Win-Shift, Lose-Shift Errors									
1	62	21	–	–	46	17	49	19	–	–	28	10	0	0
2	36	13	–	–	37	14	24	09	–	–	65	20	0	0
3	52	18	–	–	51	18	61	24	–	–	59	18	1	13
4	46	16	–	–	46	17	42	16	–	–	61	19	4	50
5	46	16	–	–	56	20	36	14	–	–	62	19	1	13
6	45	16	–	–	38	14	45	18	–	–	44	14	2	25

Table 27

Error Frequencies and Percentages by Ordinal Position

of the Fixed Ratio for Subject S6

Ordinal Position	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
1	2	09	6	15	9	18	9	16	4	08	3	14	1	03
2	5	23	4	09	6	12	0	0	12	23	8	35	2	06
3	3	14	5	12	7	14	5	09	8	15	2	09	4	13
4	0	0	1	02	1	02	5	09	5	10	1	05	0	0
5	4	18	4	09	4	08	10	18	4	08	2	09	3	09
6	5	23	6	15	4	08	9	16	7	14	1	05	3	09
7	2	09	8	19	6	12	6	11	2	04	2	09	8	25
8	0	0	4	09	5	10	3	05	2	04	0	0	7	22
9	1	04	4	09	8	16	9	16	7	14	3	14	4	13
	Win-Stay, Lose-Shift Errors													
1	1	05	2	08	5	16	4	11	2	06	2	14	1	20
2	4	21	2	08	4	13	0	0	6	19	5	37	0	0
3	2	11	2	08	2	06	5	14	4	13	2	14	0	0
4	0	0	1	04	1	03	4	11	3	09	0	0	0	0
5	4	21	2	08	4	13	7	19	3	09	1	08	0	0
6	5	26	6	24	4	13	5	14	5	16	1	07	0	0
7	2	11	4	16	2	06	3	07	1	03	0	0	2	40
8	0	0	2	08	3	10	2	05	2	06	0	0	0	0
9	1	05	4	16	6	20	7	19	6	19	3	21	2	40
	Win-Shift, Lose-Stay Errors													
1	0	0	2	50	2	25	1	20	0	0	0	0	0	0
2	0	0	1	25	2	25	0	0	2	67	0	0	1	10
3	0	0	0	0	1	13	0	0	0	0	0	0	3	30
4	0	0	0	0	0	0	1	20	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	1	.10
6	0	0	0	0	0	0	1	20	1	33	0	0	0	0
7	0	0	0	0	0	0	1	20	0	0	0	0	2	20
8	0	0	1	25	2	25	1	20	0	0	0	0	3	30
9	0	0	0	0	1	13	0	0	0	0	0	0	0	0

Table 27

Continued

Ordinal Position	Experimental Conditions A		B		C		D		E		F		G	
	Win-Stay, Lose-Stay Errors													
		%		%		%		%		%		%		%
1	1	100	0	0	1	.17	1	14	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	4	23	1	100	1	08
3	0	0	2	40	2	33	0	0	3	25	0	0	1	08
4	0	0	0	0	0	0	0	0	2	18	0	0	0	0
5	0	0	0	0	0	0	3	43	1	08	0	0	2	15
6	0	0	0	0	0	0	2	29	1	08	0	0	3	23
7	0	0	3	60	3	50	1	14	0	0	0	0	3	23
8	0	0	0	0	0	0	0	0	0	0	0	0	3	23
9	0	0	0	0	0	0	0	0	1	08	0	0	0	0
	Win-Shift, Lose-Shift Errors													
1	0	0	2	25	1	20	3	43	2	50	1	14	0	0
2	1	50	1	13	0	0	0	0	0	0	2	29	0	0
3	1	50	1	13	2	40	0	0	1	25	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	1	14	0	0
5	0	0	2	25	0	0	0	0	0	0	1	14	0	0
6	0	0	0	0	0	0	1	14	0	0	0	0	0	0
7	0	0	1	13	1	20	1	14	1	25	2	.29	1	25
8	0	0	1	13	0	0	0	0	0	0	0	0	1	25
9	0	0	0	0	1	20	2	29	0	0	0	0	2	50

Table 28

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S7

Ordinal Position	A		B		C		D		E		F		G	
						Total Errors								
		%		%		%		%		%		%		%
1	68	18	–	–	–	–	72	17	–	–	85	23	–	–
2	51	13	–	–	–	–	80	19	–	–	58	16	–	–
3	59	15	–	–	–	–	64	15	–	–	63	17	–	–
4	79	20	–	–	–	–	57	14	–	–	61	16	–	–
5	78	20	–	–	–	–	97	23	–	–	61	16	–	–
6	53	14	–	–	–	–	52	12	–	–	43	12	–	–
						Win-Stay, Lose-Shift Errors								
1	12	11	–	–	–	–	21	15	–	–	27	46	–	–
2	21	19	–	–	–	–	29	22	–	–	6	11	–	–
3	21	19	–	–	–	–	27	20	–	–	7	12	–	–
4	24	21	–	–	–	–	21	15	–	–	6	11	–	–
5	28	24	–	–	–	–	31	23	–	–	5	09	–	–
6	7	06	–	–	–	–	7	05	–	–	6	11	–	–
						Win-Shift, Lose-Stay Errors								
1	19	37	–	–	–	–	16	25	–	–	19	28	–	–
2	4	08	–	–	–	–	16	25	–	–	17	25	–	–
3	9	17	–	–	–	–	7	11	–	–	11	16	–	–
4	8	16	–	–	–	–	5	07	–	–	12	17	–	–
5	3	06	–	–	–	–	13	20	–	–	7	10	–	–
6	8	16	–	–	–	–	8	11	–	–	3	04	–	–
						Win-Stay, Lose-Stay Errors								
1	12	22	–	–	–	–	18	38	–	–	22	63	–	–
2	13	23	–	–	–	–	10	20	–	–	3	09	–	–
3	7	12	–	–	–	–	8	.16	–	–	4	11	–	–
4	16	29	–	–	–	–	3	06	–	–	0	0	–	–
5	8	14	–	–	–	–	9	18	–	–	2	06	–	–
6	0	0	–	–	–	–	1	02	–	–	4	11	–	–
						Win-Shift, Lose-Shift Errors								
1	24	14	–	–	–	–	17	10	–	–	17	08	–	–
2	13	08	–	–	–	–	25	15	–	–	33	16	–	–
3	22	13	–	–	–	–	22	13	–	–	41	19	–	–
4	31	19	–	–	–	–	28	16	–	–	43	20	–	–
5	39	23	–	–	–	–	44	26	–	–	47	22	–	–
6	38	23	–	–	–	–	36	20	–	–	30	15	–	–

Table 29

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S8

Ordinal Position	Experimental Conditions													
	A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
1	77	18	-	-	-	-	-	-	65	16	-	-	127	30
2	64	15	-	-	-	-	-	-	71	17	-	-	103	24
3	67	15	-	-	-	-	-	-	69	16	-	-	40	24
4	94	21	-	-	-	-	-	-	77	18	-	-	73	17
5	85	19	-	-	-	-	-	-	86	21	-	-	43	10
6	52	12	-	-	-	-	-	-	51	12	-	-	43	10
	Win-Stay, Lose-Shift Errors													
1	20	14	-	-	-	-	-	-	21	15	-	-	48	31
2	26	18	-	-	-	-	-	-	29	20	-	-	37	24
3	24	17	-	-	-	-	-	-	24	17	-	-	15	10
4	32	22	-	-	-	-	-	-	33	23	-	-	34	22
5	34	24	-	-	-	-	-	-	33	23	-	-	16	10
6	8	05	-	-	-	-	-	-	2	02	-	-	4	03
	Win-Shift, Lose-Stay Errors													
1	19	50	-	-	-	-	-	-	21	48	-	-	21	71
2	2	05	-	-	-	-	-	-	10	23	-	-	3	10
3	5	14	-	-	-	-	-	-	7	16	-	-	3	10
4	4	10	-	-	-	-	-	-	0	0	-	-	1	03
5	4	10	-	-	-	-	-	-	5	11	-	-	1	03
6	4	10	-	-	-	-	-	-	1	02	-	-	1	03
	Win-Stay, Lose-Stay Errors													
1	17	47	-	-	-	-	-	-	3	18	-	-	16	26
2	7	19	-	-	-	-	-	-	9	52	-	-	24	39
3	6	17	-	-	-	-	-	-	2	12	-	-	8	13
4	3	09	-	-	-	-	-	-	1	06	-	-	6	10
5	2	05	-	-	-	-	-	-	2	12	-	-	7	.12
6	1	03	-	-	-	-	-	-	0	0	-	-	0	0
	Win-Shift, Lose-Shift Errors													
1	21	10	-	-	-	-	-	-	20	10	-	-	42	23
2	29	13	-	-	-	-	-	-	24	11	-	-	39	21
3	32	14	-	-	-	-	-	-	36	16	-	-	14	08
4	55	25	-	-	-	-	-	-	43	20	-	-	32	17
5	45	20	-	-	-	-	-	-	46	21	-	-	19	10
6	39	18	-	-	-	-	-	-	48	22	-	-	38	.21

Table 30

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S9

Ordinal Position	A	A %	B	B %	C	C %	D	D %	E	E %	F	F %	G	G %
Total Errors														
1	0	0	–	–	–	–	1	05	–	–	5	71	13	57
2	0	0	–	–	–	–	2	11	–	–	2	29	6	26
3	0	0	–	–	–	–	2	11	–	–	0	0	3	13
4	0	0	–	–	–	–	5	28	–	–	0	0	0	0
5	0	0	–	–	–	–	6	34	–	–	0	0	1	.04
6	0	0	–	–	–	–	2	11	–	–	0	0	0	0
Win-Stay, Lose-Shift Errors														
1	0	0	–	–	–	–	0	0	–	–	0	0	2	100
2	0	0	–	–	–	–	0	0	–	–	0	0	0	0
3	0	0	–	–	–	–	0	0	–	–	0	0	0	0
4	0	0	–	–	–	–	1	25	–	–	0	0	0	0
5	0	0	–	–	–	–	1	25	–	–	0	0	0	0
6	0	0	–	–	–	–	2	50	–	–	0	0	0	0
Win-Shift, Lose-Stay Errors														
1	0	0	–	–	–	–	0	0	–	–	0	0	5	83
2	0	0	–	–	–	–	0	0	–	–	1	100	1	17
3	0	0	–	–	–	–	0	0	–	–	0	0	0	0
4	0	0	–	–	–	–	0	0	–	–	0	0	0	0
5	0	0	–	–	–	–	2	100	–	–	0	0	0	0
6	0	0	–	–	–	–	0	0	–	–	0	0	0	0
Win-Stay, Lose-Stay Errors														
1	0	0	–	–	–	–	1	08	–	–	5	100	6	40
2	0	0	–	–	–	–	2	17	–	–	0	0	5	33
3	0	0	–	–	–	–	2	17	–	–	0	0	3	20
4	0	0	–	–	–	–	4	33	–	–	0	0	0	0
5	0	0	–	–	–	–	3	25	–	–	0	0	1	07
6	0	0	–	–	–	–	0	0	–	–	0	0	0	0
Win-Shift, Lose-Shift Errors														
1	0	0	–	–	–	–	0	0	–	–	0	0	0	0
2	0	0	–	–	–	–	0	0	–	–	1	100	0	0
3	0	0	–	–	–	–	0	0	–	–	0	0	0	0
4	0	0	–	–	–	–	0	0	–	–	0	0	0	0
5	0	0	–	–	–	–	0	0	–	–	0	0	0	0
6	0	0	–	–	–	–	0	0	–	–	0	0	0	0

Table 31

Error Frequencies and Percentages by Ordinal Position of

the Fixed Ratio for Subject S10

Ordinal Position	Experimental Conditions A		B		C		D		E		F		G	
	Total Errors													
		%		%		%		%		%		%		%
1	3	04	–	–	–	–	–	–	0	0	7	27	5	05
2	6	08	–	–	–	–	–	–	4	12	4	15	4	04
3	13	17	–	–	–	–	–	–	5	14	1	04	15	15
4	15	19	–	–	–	–	–	–	8	23	1	04	20	20
5	19	24	–	–	–	–	–	–	6	17	1	04	28	29
6	22	28	–	–	–	–	–	–	12	34	12	46	26	27
	Win-Stay, Lose-Shift Errors													
1	2	04	–	–	–	–	–	–	0	0	5	29	0	0
2	4	08	–	–	–	–	–	–	2	12	1	06	0	0
3	8	16	–	–	–	–	–	–	1	06	1	06	4	14
4	10	20	–	–	–	–	–	–	2	12	1	06	1	03
5	12	24	–	–	–	–	–	–	6	35	0	0	2	07
6	15	28	–	–	–	–	–	–	6	35	9	53	22	76
	Win-Shift, Lose-Stay Errors													
1	0	0	–	–	–	–	–	–	0	0	0	0	3	
2	0	0	–	–	–	–	–	–	0	0	0	0	0	0
3	1		–	–	–	–	–	–	0	0	0	0	0	0
4	0	0	–	–	–	–	–	–	0	0	0	0	0	0
5	0	0	–	–	–	–	–	–	0	0	0	0	0	0
6	0	0	–	–	–	–	–	–	0	0	0	0	0	0
	Win-Stay, Lose-Stay Errors													
1	1	04	–	–	–	–	–	–	0	0	2	40	2	03
2	2	08	–	–	–	–	–	–	2	12	0	0	4	06
3	4	15	–	–	–	–	–	–	4	22	0	0	11	17
4	5	19	–	–	–	–	–	–	6	33	0	0	19	29
5	7	27	–	–	–	–	–	–	0	0	0	0	26	39
6	7	27	–	–	–	–	–	–	6	33	3	60	4	06
	Win-Shift, Lose-Shift Errors													
1	0	0	–	–	–	–	–	–	0	0	0	0	0	0
2	0	0	–	–	–	–	–	–	0	0	3	75	0	0
3	0	0	–	–	–	–	–	–	0	0	0	0	0	0
4	0	0	–	–	–	–	–	–	0	0	0	0	0	0
5	0	0	–	–	–	–	–	–	0	0	1	25	0	0
6	0	0	–	–	–	–	–	–	0	0	0	0	0	0

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