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AUTHOR Hartley, Deborah G.
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ABSTRACT

The present study examines the relationship between alternation behavior and performance, and in addition, the effects of reinforcement configuration and relevant dimension upon the use of alternation strategies in probability learning. Also investigated is the hypothesis that children's errors at terminal levels of performance in a two-choice probability learning situation are attributable to errors resulting from attention to irrelevant dimensions. Subjects were 31 third grade and 47 fourth grade children who were given a two-choice probability learning task in which one relevant dimension (brightness or position) and one irrelevant dimension (position or brightness) were present. One of two reinforcement probabilities (2:1 or 5:1) was utilized. Children's preferences for aspects of the irrelevant dimension were found to account for more errors than would be expected by chance. The use of alternation strategies was differentially affected by both the reinforcement probability and the relevant dimension employed in the task. The results offered some support for the hypothesis that errors at terminal levels of performance can be accounted for by attention to irrelevant dimensions. An important finding was that the relationship between alternation strategies and performance was jointly determined by the relevant dimension and the reinforcement configuration employed. (Author/MS)

Children's Probability Learning: An Analysis of Errors

Deborah G. Hartley, College of William and Mary

Abstract

Third- and fourth-grade children were given a two-choice probability learning task in which one relevant dimension (brightness or position) and one irrelevant dimension (position or brightness) were present. One of two reinforcement probabilities (2:1 or 5:1) was utilized. Children's preferences for aspects of the irrelevant dimension were found to account for more errors than would be expected by chance. The use of alternation strategies was differentially affected by both the reinforcement probability and the relevant dimension employed in the task. The results offered some support for the hypothesis that errors at terminal levels of performance can be accounted for by attention to irrelevant dimensions. More important, however, was the finding that the relationship between alternation strategies and performance was jointly determined by the relevant dimension and the reinforcement configuration employed.

Children's Probability Learning: An Analysis of Errors[1]

Investigators of children's probability learning have been particularly interested in developmental changes in maximizing behavior; i.e., the tendency to consistently choose the stimulus receiving the greatest percentage of reinforcement such that reward is maximized. Weir (1964) noted that, in a number of studies of probability learning in humans, a U-shaped function best describes the relationship between maximization and age. In general, subsequent research (Derks & Paclisanu, 1967; Sullivan & Ross, 1970) has confirmed this U-shaped relationship between maximizing behavior and age. An inverted U-shaped function between age and simple response patterns, such as single alternation, was also noted by Weir. He proposed that the relatively poor performance exhibited by children between the ages of 7 and 15 could be the result of their frequent use of inappropriate alternation patterns. While Weir (1964) found that alternation responses occurred consistently across trials in children aged 7-15, he noted in a later study (1967) that alternation responses decreased across trials for subjects of all ages. A decrease in alternation patterns across trials has also been reported by other experimenters (Sullivan & Ross, 1970; Dusek & Hill, 1970). Such results seem to indicate that the use of simple hypotheses such as single alternation cannot be cited as the sole source of failure of middle-aged children to maximize. Moreover, the role of alternation strategies in producing poor terminal levels of performance remains unclear.

Investigations of the failure of animals to maximize in probability learning situations (Sutherland & Mackintosh, 1971; Mackintosh, 1970) have also sought to identify the processes involved in producing relatively poor terminal levels of performance. Sutherland and Mackintosh designate the choices in a two-choice probability learning task as the "majority" and the "minority" cue (the former being the cue receiving the larger percentage of reinforcement and the latter the stimulus cue receiving the smaller percentage of reinforcement). Any choice of the minority cue is regarded as an "error." They state that errors may be due either to a momentary preference for the minority cue or to a failure to attend to the relevant dimension in the stimulus situation. Mackintosh (1970) has reported a number of experiments in which failure to maximize in rats has been attributable to attention to irrelevant dimensions. It seems reasonable to hypothesize that such attentional failures may also be a major source of terminal-level-of-performance errors for children of 7-15 years of age.

The purpose of the present study was to further examine the relationship between alternation behavior and performance and, in addition, the effects of reinforcement configuration and relevant dimension upon the use of alternation strategies. Furthermore, the study was designed to investigate the hypothesis that children's errors at terminal levels of performance in a two-choice probability learning situation are attributable to errors resulting from attention to irrelevant dimensions. For these purposes, four groups of children were trained in a two-choice probability learning task. Two reinforcement probabilities, 83 1/3:16 2/3 (5:1), and, 66 2/3:33 1/3 (2:1), and two relevant dimensions (position or brightness) were administered such that each of the four groups received one reinforcement condition and were trained with one relevant dimension and one irrelevant dimension.

The type of error analysis employed by Sutherland and Mackintosh (1971) requires that the child be provided with information as to which cue is rewarded on any given trial, whether or not he receives the reward. Since there is evidence (Spence, 1966) that, in the absence of other instructions, children regard "blank" trials as correct responses, a reward-punishment procedure (see Whitehurst, 1969) was included in the present experiment. Such a procedure assures that the child knows when he is not receiving reinforcement and can be assumed to provide him with the necessary information regarding which cue is rewarded on each trial.

Method

Subjects

The subjects were 31 third-grade and 47 fourth-grade children, mean age = 119 months and S.D. = 9 months, enrolled in Crozet Elementary School, Albemarle County, Virginia. Within each grade level, approximately equal numbers of male and female subjects were randomly assigned to each of the four experimental groups. Two of the groups were composed of 20 children each while the remaining two groups each included 19 children.

Apparatus

A turntable and screen device was used for the presentation of stimulus cards. The 12 x 31 in. screen was positioned perpendicular to the 18 in. diameter turntable and attached to it by a metal rod such that the turntable could rotate freely beneath the screen. Both turntable and screen were constructed of plywood and painted flat beige. The turntable contained four 4 x 6 in. openings for the placement of stimuli. Two of these openings were positioned side-by-side, lengthwise, 1 in. apart, and the other two were similarly located on the opposite side of the turntable. All of the openings were recessed with an internal edge such that the stimulus cards could like flush with the surface of the turntable. A depression 1/2 in. in diameter centered in each of the stimulus receptacles allowed for the placement of a marble. Small beveled areas on all four sides of each receptacle permitted a child to remove a stimulus card to determine whether or not a marble had been placed in the depression. The turntable arrangement allowed for the presentation of two stimuli to the child while the experimenter, concealed behind the screen, placed the two cards and a marble in the appropriate positions for the next trial. Two triangular pieces of plywood, 12 in. high with a base of 18 in., were attached to the edges of the screen in order to provide additional support for the apparatus. The experiment was conducted in a small classroom in the basement of the main school building.

Procedure and Experimental Design

Two reinforcement probabilities were administered such that the children in the 5:1 Groups were reinforced for one value of the relevant dimension on 60 of the 72 experimental trials and for the other value of the relevant dimension on the remaining 12 trials, whereas subjects in Groups 2:1 were reinforced for one value of the relevant dimension on 48 of the trials and for the other value on the other 24 trials. The schedules were such that subjects in Groups 5:1 received two minority cue rewards in every 12-trial block, whereas the 2:1 Groups received four minority cue rewards in each block of 12 trials. For Groups 5:1 minority cue rewards never occurred on successive trials whereas for the 2:1 Groups no more than two minority cue rewards occurred on successive trials. For half of the children in each reinforcement condition, brightness was the relevant dimension and position was an irrelevant dimension, while for the other half position was the relevant dimension and brightness was an irrelevant dimension. The spatial placement of the stimuli was determined by the series developed by Fellows (1967). In addition, for half of the subjects in each group one value of the relevant dimension (either light or dark if brightness was the relevant dimension, right or left if position was relevant) was designated as the majority cue for the remaining subjects. The stimulus cards presented in the experiment were 4 x 6 in. sheets of silk screen paper glued to plain white 4 x 6 index cards. Two brightnesses of gray silk screen paper were used; as measured by a Gamma photometer the lighter gray had a reflectance of 29.7% and the darker gray had a reflectance of 10.5%.

Each child arrived at the testing room at a time pre-arranged with the child's teacher. The child was greeted by name upon entering the room and was shown a table containing an assortment of 7 toys. He was told, "These are the prizes you can win in this game," and was permitted to look at them briefly. The child was then seated at a table to the left of the prize table such that the apparatus was directly in front of him and the prize table was to his right. He was then given the following instructions: The object of this game is to get as many marbles as you can, because if you have enough marbles at the end of the game you may choose a prize. During the game you will see these two cards. Each time you see the cards you may choose one. Each time you choose, one card will be right and will have a marble under it, the other card will be wrong and will not have a marble under it. I want you to always try to choose the correct card because that is the only way you can get marbles. If you choose the wrong card you will have to give me a marble back, so I will give you these marbles to start the game with. (The subject was handed a plastic container which held 25 marbles.) Then each time you see the cards, I want you to pick up the card you think has the marble under it and hand the card to me. Do you have any questions?

Any questions were answered by repeating the appropriate section(s) of the instructions, and the child was then asked his age and birthdate. The child was then told to pick up the card he thought had the marble under it. Regardless of the outcome of this trial the child was then told "All right, let's try again." After the second trial, comments were made only if the child was not following instructions (i.e., if the child did not give back a marble when he failed to choose the reinforced stimulus). Each subject received 72 trials.

All marbles "won" by the child were added to the container given to him at the beginning of the experiment. Immediately following the last trial, the child was told "That's the end of the game, let's see how many marbles you have." The container was briefly examined, and the child was told "That's plenty enough to win a prize; would you like to choose one?"

Results

Inspection of the mean percentages of correct responses data (i.e., choices of the majority cue) indicated that the performance curves separated after approximately the 30th trial such that the two 5:1 Groups chose consistently better than both 2:1 Groups. Examination of the group data revealed that the choice data were relatively stable over the final 24 trials. The mean percentages of majority cue selections over the final 24 trials were 57.24%, 53.75%, 69.79%, and 76.76% for the 2:1 Brightness-Relevant, 2:1 Position-Relevant, 5:1 Brightness-Relevant, and 5:1 Position-Relevant Groups, respectively.

To determine the effects of Reinforcement Probability (2:1 vs. 5:1) and Relevant Dimension (brightness vs. position), a 2 x 2 Analysis of Variance was performed on each subject's total number of correct responses. The results of this analysis revealed that the 5:1 Groups made significantly more majority cue selections than the 2:1 Groups ($F_{(1,74)}=18.15$, $p<.001$). There was no Relevant Dimension effect and the Relevant Dimension x Reinforcement Probability interaction was not significant. A Chi-square analysis of each of the 2:1 Groups' errors over the last 24 trials revealed that neither of these groups was performing reliably above the 50% chance level. Mann-Whitney $\underline{U}$ tests indicated that the sex and grade level of the children had no significant effect on the terminal level of performance of any of the groups. The response protocols were inspected to determine if there were any group preferences for values of the relevant and/or irrelevant dimension. While subjects in Group 5:1 Brightness-Relevant showed a statistically significant preference ($\underline{Z} = 6.45$, $p < .001$) for the darker of the two stimuli (although the lighter stimulus was designated as correct for half of the children in this group) no other preferences for values of relevant or irrelevant dimensions were observed.

Mean percentages of reward (calculated from the number of times the children received a marble regardless of which cue was chosen) for each of the groups over the last 24 trials indicated that the 2:1 Groups received an average of approximately 65% of the trials. The number of subjects performing above and below matching levels over the final 24 trials for each group are presented in Table 1. As can be seen from an examination of Table 1, it appears that relatively more subjects in the 5:1 Groups than the 2:1 Groups performed above their respective matching levels. Separate Chi-square analyses of the data for the Position-Relevant Groups and for the Brightness-Relevant Groups revealed that with respect to the Position-Relevant Groups, performance above matching level was contingent upon the reinforcement probability

($X^2 = 8.69$, $df = 1$, $p < .01$); whereas the two Brightness-Relevant Groups did not differ statistically with regard to the distribution of the number of subjects performing above and below matching levels.

Insert Table 1 about here

Of the children who performed above matching levels in Group 2:1 only one subject (who was in the Brightness-Relevant condition) was maximizing (choosing the majority cue on more than 90% of the trials; i.e., on 22 or more of the last 24 trials) while of those above matching in Groups 5:1 all five of the children in the Brightness-Relevant Group and 7 out of 10 of those in the Position-Relevant Group were maximizing.

The number and type of errors committed by each subject over all 72 trials was determined by applying error analyses described by Mackintosh (1970). Each subject's responses over all 72 experimental trials were inspected to determine if they demonstrated a preference for one value of the irrelevant dimension on 40 or more of 72 trials is approximately 41%.

The observed percentages of errors along with the percentages of errors expected by chance are presented in Table 2. Error data for the Brightness-Relevant Groups are presented in the top half of Table 2, while the data for the Position-Relevant Groups are included in the lower portion of the table. In the first column of both portions of the table are errors (minority cue choices) which occurred on trials immediately following a trial on which the minority cue was designated as the cue to be rewarded. Errors due to the choice of the minority cue when it coincides with the last rewarded value of the irrelevant dimension (reward-following on the irrelevant dimension) are presented in the second columns. The errors presented in the third column are those due to the child's choice of the aspect of the irrelevant dimension that he has shown a preference for. It is evident from an inspection of Table 2 that errors due to preferences for one value of the irrelevant dimension account for significantly more errors than would be expected by chance for all groups except Group 5:1 Position-Relevant; for this group the results approached the conventional significance level. The occurrence of other types of errors was not significantly different from that expected by chance. The observed percentages of errors did not vary systematically with level of performance, except in the case of the children performing above matching levels in Group 2:1 Brightness-Relevant for whom there were significantly less errors following minority cue rewards than would be expected by chance ($\underline{Z} = -2.20$, $\underline{p} < .05$).

Insert Table 2 about here

Each subject's responses over all 7? trials were analyzed for single alternation, double alternation, and 2:1 alternation on the relevant dimension in the manner described by Sullivan and Ross (1970). Briefly, five or more consecutive alternations were required for categorizing responses as single alternations while six or more consecutive responses in the appropriate pattern were required for categorizing responses as double or 2:1 alternations. In addition, any response that could be categorized as belonging to more than one sequence was only counted once; moreover, it was always considered as the last response in an ongoing pattern rather than the first response in a new pattern. The mean percentages of trials and errors accounted for by alternation responses are presented in the left- and right-hand portions of Figure 1, respectively. With regard to the Position-Relevant Groups, an examination of the left-hand portion of Figure 1 indicates that alternation responses occurred more frequently across trials for Group 2:1 but less frequently as trials progressed for Group 5:1. For the Brightness-Relevant Groups across all three trial blocks, Group 2:1 exhibited more alternation than Group 5:1. There was a slight decline in alternation across trials for both Brightness-Relevant Groups. A 2 x 2 x 3 Analysis of Variance performed on the alternation behavior of each subject for each of the three trial blocks resulted in significant main effects for Reinforcement Probability ($\underline{F}_{(1,74)} = 9.74$, $\underline{p} < .005$), Trials ($\underline{F}_{(2,148)} = 3.07$, $\underline{p} < .05$) and a significant Reinforcement Probability X Trials interaction ($\underline{F}_{(2,148)} = 4.71$, $\underline{p} < .01$). The Reinforcement Probability X Relevant Dimension X Trials interaction approached the conventional level of significance ($\underline{F}_{(2,148)} = 2.74$, $\underline{p} < .10$). With regard to the right-hand portion of Figure 2, Group 2:1 Position-Relevant shows a large increase across trials in the percentage of errors accounted for by alternation. For the remaining three groups the percentage of errors accounted for by alternation remains relatively consistent across trials. For the Brightness-Relevant Groups, alternation accounts for more errors in Group 2:1

than in Group 5:1. In that errors decline across trials, the data points representing the p. centage of errors become increasingly less reliable with further training. Looking at both segments of Figure 1, it should be noted that alternation generally accounts for a greater percentage of errors than trials.

Insert Figure 1 about here

Discussion

It should be noted that the performance data are in accord with previous findings of Weir (1964) and others that middle-aged children attain terminal levels of responding which fall below matching levels. The overall percentage of subjects maximizing is also similar to that observed for middle-aged children by Weir (1964). The general similarity of the overall performance and degree of maximizing at terminal level of performance in the current investigation to that observed by other researchers indicates that the somewhat atypical "punishment" procedure did not drastically affect the results.

Investigators of alternation behavior in probability learning tasks (Weir, 1964; 1967; Sullivan & Ross, 1970; Dusek & Hill, 1970) have all reported increases in alternation as reinforcement to the majority cue decreases. In the present study this variation of alternation with reinforcement was also observed. It appears that the differences in the number of subjects performing above and below matching levels in the Position-Relevant Groups can be attributed to the greater use of alternation responses by the children in the 2:1 Group. The differences in alternation behavior can probably be explained as follows. When position is the relevant dimension, a 2:1 reinforcement configuration results in a pattern of rewards which approximates a type of alternation strategy. When the reinforcement condition is 5:1 and position is the relevant dimension, however, an alternation strategy would rarely receive reinforcement on the minority cue. Although the same differential reinforcement of alternation would apply for Group 2:1 vs. Group 5:1 when brightness is the relevant dimension it seems, intuitively, that the pattern of rewards resulting from brightness alternation (when position is irrelevant) would be more difficult to follow than that resulting from position alternation. As a consequence, the differences in alternation behavior between a 2:1 Group and a 5:1 Group when brightness is relevant would not be expected to increase as much as a function of successive blocks of training. Interestingly enough these results indicate that when position is a relevant dimension and reinforcement to the majority cue is relatively low, subjects attend to more than one aspect of the position dimension. When brightness is the relevant dimension, however, there is a smaller change across trial blocks in the number of alternation responses displayed under the two reinforcement probabilities, and the amount of alternation behavior observed is considerably less than that found in the 2:1 Group where position was the relevant dimension. The fact that there were increasing differences between the Position-Relevant Groups across trials but not the Brightness-Relevant Groups is especially significant because all of the previous studies reporting on alternation behavior in probability learning employed a task in which position was a relevant dimension. The decrease in alternation across trials reported by some investigators (Weir, 1967; Sullivan & Ross, 1970; Dusek & Hill, 1970) seems most characteristic of the 5:1 Position-Relevant Group. For the Brightness-Relevant Groups the decline of alternation behavior across trials was very slight while for Group 2:1 Position-Relevant there was actually an increase in alternation responding. Thus, prior experiments concerned with the role of alternation behavior in developmental changes in probability learning may be reporting effects that are due, in some undetermined manner to the reinforcement probabilities employed and the use of position as a relevant dimension.

Previous investigators of alternation behavior ability learning tasks have failed to report the percentage of errors (minority cue selections) due to the use of alternation strategies. While the percentage of errors accounted for by alternation in the present study was, in general, greater than the percentage of trials on which alternation occurred for all groups, there was a much larger proportion of errors than trials accounted for by alternation in the 5:1 Groups than the 2:1 Groups. This result was particularly pronounced when position was the relevant dimension. While the percentage of trials on which alternation occurred declined rapidly across trials for Group 5:1 Position-Relevant, the percentage of errors attributable to alternation remained consistently around 50%. Thus, it is clear that alternation strategies were a major source of errors for the group. As would be expected alternation accounted for more errors when the reinforcement condition was 2:1 than when it was 5:1 and when the relevant dimension was position rather than brightness.

The error analyses provide minimal support for the applicability of the Sutherland and Mackintosh (1971) model to the probability learning of middle-aged children. Although Sutherland and Mackintosh predict that a greater number of errors than expected by chance should be attributable both to preferences for values of the irrelevant dimension and choice of the minority cue when it coincides with the last rewarded value of the irrelevant dimension, only errors due to preferences occurred above chance levels. One obvious prediction of the model is that less errors of all types should occur in Groups 5:1 than in Groups 2:1; this prediction was supported.

The data in the current study do indicate that attentional processes in the form of preferences for values of irrelevant dimensions may play a role in the failure of middle-aged children to maximize in probability learning situations. In addition, the present findings indicate that the role of alternation strategies in probability learning is a complex one, differentially affected by both the relevant dimension and the reinforcement probability employed in the task. It seems clear that the use of position as a relevant dimension in virtually all investigations of developmental changes in probability learning has led to a somewhat distorted view of the role of alternation strategies in such tasks.

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Table 1

Number of Ss Performing Above and Below Matching Levels

Over Final 24 Trials

	Reinforcement Probability 2:1			5:1			Totals		
Above	6_B	1_P	(7)	5_B	10_P	(15)	11_B	11_P	(22)
Below	13_B	19_P	(32)	15_B	9_P	(24)	28_B	28_P	(56)
Totals	19_B	20_P	(39)	20_B	19_P	(39)	39_B	39_P	(78)

Subscripts B and P refer to Brightness-Relevant and Position-Relevant Groups, respectively. Numbers in parentheses are totals for Brightness- and Position-Relevant Groups combined.

Table 2

Percentages of Errors Occurring on Final 24 Trials

Relevant Dimension

Brightness

Probability	Following Minority Stimulus Rewards	When Minority Cue is in Last Rewarded Position*	When Minority Cue is in Preferred Position
2:1	(Chance = 20.83) 16.41 (N = 19)	(Chance = 37.50) 39.49 (N = 19)	(Chance = 50.00) 60.52[a] (N = 7)
5:1	(Chance = 16.67) 17.93 (N = 20)	(Chance = 41.67) 44.83 (N = 20)	(Chance = 50.00) 64.90[b] (N = 12)

[a]$Z = 1.72$, $p < .05$ (one-tailed) [b]$Z = 2.78$, $p < .005$ (one-tailed)

Position

Reinforcement	Following Minority Side Rewards	When Last Rewarded Brightness is on Minority Side*	When Preferred Brightness is on Minority Side
2:1	(Chance = 20.83) 19.37 (N = 20)	(Chance = 37.50) 39.19 (N = 20)	(Chance = 50.00) 58.71[c] (N = 10)
5:1	(Chance = 16.67) 17.92 (N = 19)	(Chance = 37.50) 40.57 (N = 19)	(Chance = 50.00) 59.01[d] (N = 9)

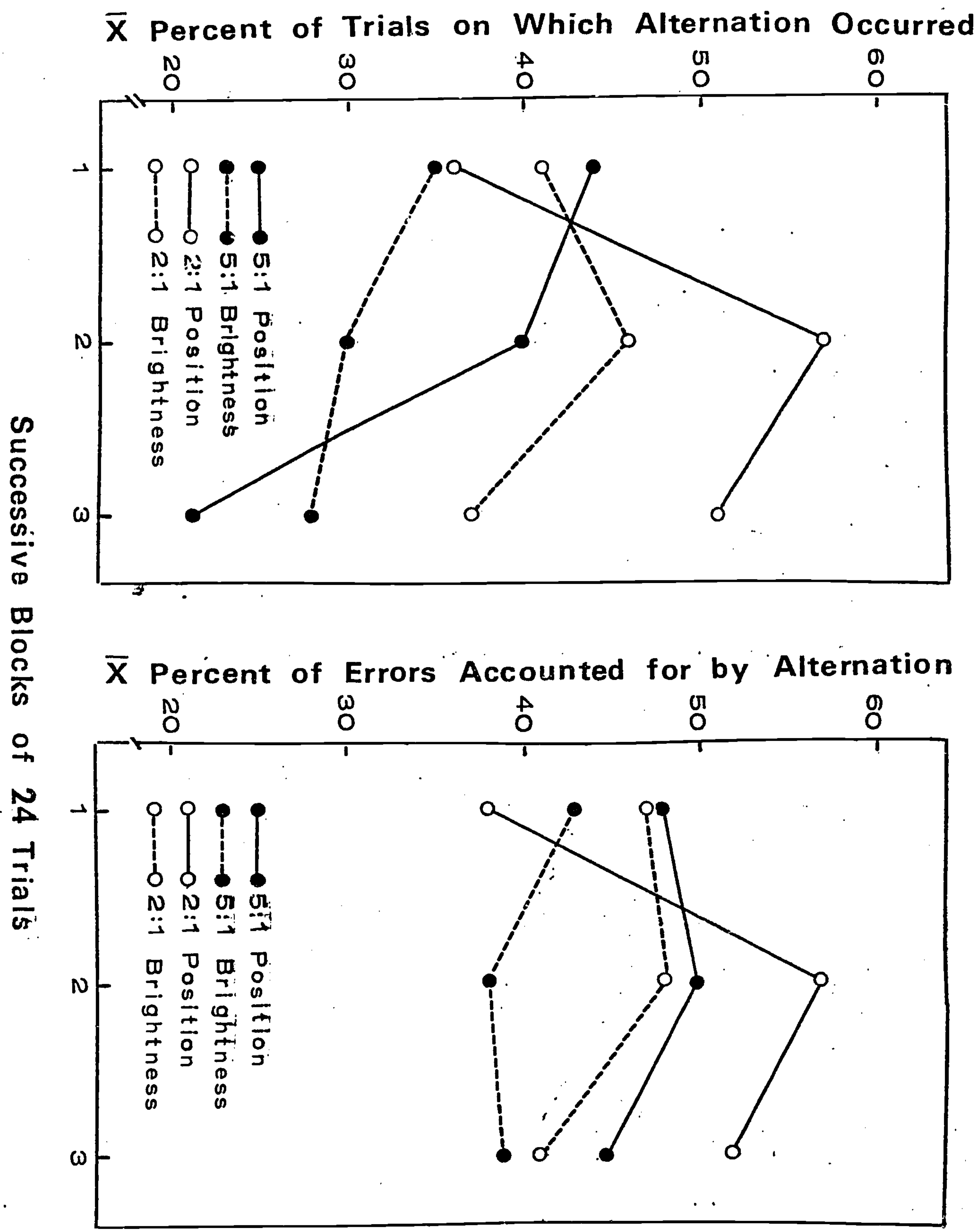
[c]$Z = 1.72$, $p < .05$ (one-tailed) [d]$Z = 1.28$, $p < .10$ (one-tailed)

Ns in columns 1 and 2 are total Groups Ns while those in column 3 are for only those Ss showing a preference.

*These errors can also be categorized as reward-following on the irrelevant dimension.

Figure Caption

Mean percentages of trials and errors accounted for by alternation responses.


X̄ Percent of Trials on Which Alternation Occurred
X̄ Percent of Errors Accounted for by Alternation
5:1 Position
5:1 Brightness
2:1 Position
2:1 Brightness
Successive Blocks of 24 Trials

Footnotes

1. This research was supported by National Science Foundation Grant GB-13341 awarded to M. J. Homzie, University of Virginia.