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A Developmental Study of Sign-Differentiated and Non-Sign-Differentiated Conditional Discrimination Learning.

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The ability to make relational discriminations, i.e., to solve problems by responding to the relationships between cues rather than to the absolute properties of individual cues, is examined. The laboratory analogy of this type of problem is referred to as a conditional discrimination problem. Mr. Grogg empirically demonstrates the difference between a sign-differentiated (SD) and a nonsign-differentiated (NSD) conditional discrimination problem, the former not necessarily requiring a relational rule for solution, but the latter necessarily involving true relational learning. By testing sixth graders, 10th graders and college sophomores, data is provided concerning the developing ability to solve such problems. The results indicated that at each grade level, the NSD problem was more difficult than the SD problem. Also revealed was a monotonic developmental trend in conditional problem-solving ability. The results were interpreted in terms of a hierachy of response tendencies, and a differential cognitive requirement. (Author)

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Technical Report No. 55

A DEVELOPMENTAL STUDY OF SIGN-DIFFERENTIATED AND NON-SIGN-DIFFERENTIATED CONDITIONAL DISCRIMINATION LEARNING

By Tommy Michael Grogg

Report from the Rule Learning Project
Harold J. Fletcher, Principal Investigator

Wisconsin Research and Development
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The University of Wisconsin
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PREFACE

This technical report is based upon the Master's thesis of Tommy Michael Grogg. The examining committee consisted of Professors Harold J. Fletcher (chairman), Leonard Ross, and Gene Sackett.

One major program of the Wisconsin R and D Center for Cognitive Learning is Program 1 which is concerned with fundamental conditions and processes of learning. This program consists of laboratory-type research projects, each independently concentrating on certain basic organismic or situational determinants of cognitive learning, but all attempting to provide knowledge which can be effectively utilized in the construction of instructional systems for tomorrow's schools.

Of critical importance to everyday learning is the ability to make relational discriminations, i.e., to solve problems by responding to the relationships between cues rather than to the absolute properties of individual cues. The laboratory analogy of this type of problem is referred to as a conditional discrimination problem. In his thesis, Mr. Grogg first empirically demonstrates the difference between a sign-differentiated and a non-sign-differentiated conditional discrimination problem, the former not necessarily requiring a relational rule for solution but the latter necessarily involving true relational learning. Secondly, by testing 6th graders, 10th graders, and college sophomores, his thesis provides data concerning the developing ability to solve such problems. Significantly, his research emphasizes the difficulty that 6th grade children apparently have in applying a relational rule.

Harold J. Fletcher
Director of Program 1

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ABSTRACT

Students from three different grade levels— sixth (N=40), tenth (N=40), and college sophomore (N=64)— were presented two different two-choice conditional discrimination problems to solve. The non-sign-differentiated (NSD) conditional problem consisted of three different stimulus elements (A, B, C) presented in three different combinations (AB, BC, CA) with each element being positive in one combination and negative in the other. In order to solve the NSD problem, S had to respond to the conditional relationship between the stimulus elements. The sign-differentiated (SD) conditional problem was identical to the NSD problem, with the exception that each stimulus combination was a different color. Thus, this SD problem could have been solved by responding to the conditional relationship between stimulus elements (as required in the NSD problem) or by responding to a compound of a specific element and a particular color (e.g., blue A was always correct). The results indicated that at each grade level the NSD problem was more difficult than the SD problem. Also revealed was a monotonic developmental trend in conditional problem-solving ability. The results were interpreted in terms of 1) a hierarchy of response tendencies, and 2) a differential cognitive requirement.

I
INTRODUCTION

One of the interesting controversies in psychology's past was concerned with the question of what response is learned in a two-choice discrimination situation, such as the situation involving a Lashley jumping stand. In this situation rats jump to either of two doors or cards which differ along some dimension (e.g., brightness level). Nissen (1952) and other theorists have hypothesized that an approach response to a consistently reinforced stimulus element (e.g., white) was learned in such a situation. Other theorists, such as Gulliksen and Wolfle (1938) and Weise and Bitterman (1951) have taken the position that Ss learned directional responses to the two spatial configurations formed by the two main stimulus elements (e.g., black and white). In other words, a rat learned to make a right jumping response to the total spatial configuration of "black-white" but a left jumping response to the "white-black" configuration.

An essentially equivalent question and one of greater importance for this study is the question concerning what the effective stimulus is in a two-choice discrimination problem. Nissen and others taking a similar position have assumed that the stimulus controlling behavior was an independent stimulus element. In contrast to this conception, Weise and Bitterman (1951) conceived of the effective stimulus as being a total configuration or pattern involving both stimulus elements.

One of the main conclusions derived from the research of Bitterman and of Nissen was that the effective stimulus is largely determined by the specific structure of the discrimination problem (i.e., the manner in which the stimulus elements are presented or the type of extraneous cues involved). However, Spence (1952), in discussing the question of the effective stimulus, continued to maintain that the reinforcement contingencies in a discrimination problem were more important than the specific structure of the problem in determining the stimulus to which the S would respond. He hypothesized that inarticulate organisms would not respond to the total configuration of the stimulus elements in a two-choice discrimination problem if an individual element, or a compound of an element and an extraneous cue (e.g., position) were consistently reinforced throughout the presentation of the problem.

As an example of a two-choice problem in which no individual element or compound would be consistently reinforced, Spence (1952) described a "transverse patterning" discrimination problem. This problem utilizes three different stimulus elements, but only two are presented on any one trial. Hence, there would be three different two-stimulus combinations. For example, if the three stimulus elements were a circle, a square, and a triangle, the three stimulus combinations would be circle-square, square-triangle, and triangle-circle. Each of the figures would always be correct in one of the combinations in which it appeared and always incorrect in the other combination. Thus if each of the three combinations were presented equally often, each figure would be correct only 50 percent of the time. Since each figure would be correct only in a particular combination, the correctness or incorrectness of a given figure would be conditional upon the other figure with which it is paired. If the above figures were used as stimulus elements, the correct solution to the transverse problem could be conceptualized as follows: circle>square, square>triangle, and triangle>circle.

In a study involving conditional discrimination learning, Honeck (1966) classified Spence's transverse problem as a non-sign-differentiated (NSD) conditional discrimination problem. This designation emphasized that there was no extraneous cue or sign (e.g., color, position) to indicate the correct stimulus element. The transverse problem can be changed from a NSD conditional problem to a theoretically simpler sign-differentiated (SD) conditional problem by making each of the three stimulus combinations a different color. For example, using the above figures as stimulus elements, an SD problem could be devised by making both figures in the circle-square combination blue, both figures in the square-triangle combination red, and both figures in the triangle-circle combination yellow. Under these conditions the correct stimulus element in each combination could be chosen by responding to a particular element in combination with a particular color, rather than by responding to the conditional relationship between two separate elements. The color of the stimulus combination, thus, would act as a sign to indicate the correct stimulus element, and the correct solution to this SD problem could be conceptualized as follows: blue circle, red square, and yellow triangle.

Most previous research on conditional discrimination learning has involved SD problems rather than NSD problems. Moreover, the SD problems used have been simpler than the one described above in that only two stimulus elements were involved. In one of the earliest of these studies (Lashley, 1938), an upright triangle and an inverted triangle were presented together on two different backgrounds (black and striped). It is of particular importance to consider the procedure used in presenting the two different combinations of figures and backgrounds. Rats were run to criterion first on one of the combinations and then on the other. After criterion had been reached on both, the combinations were then presented randomly until criterion was reached again. Many other studies involving rats (North, Maller, and Hughes, 1958), primates (Nissen, Blum, and Blum, 1949), and young children (Gollin and Liss, 1962; Gollin, 1964) have been conducted using basically the same procedure, and they have shown that all the various types of Ss were capable of making the SD conditional discriminations.

Very few studies, however, have been conducted using the NSD type of conditional problem with either humans or nonhumans. Nonetheless, this type of problem is theoretically interesting, since it permits an evaluation of ability to solve two-choice discrimination problems which require a consideration of both stimulus elements on each trial in order to make a correct response. Nissen (1942) gave chimpanzees a complex NSD problem involving four stimuli which appeared in four different combinations. In a procedure similar to that of Lashley (1938), he required the Ss to reach criterion on each of the individual combinations before presenting all of the combinations together in a random sequence. According to French (1965), this procedure represented an indirect attempt to force the Ss to make appropriate observing responses to both stimulus elements in each stimulus combination. The results revealed that the chimpanzees were capable of making NSD conditional discriminations. In a partial replication of this study, Noer and Harlow (1946) found that monkeys could also make such discriminations, but not with the same proficiency as did the chimpanzees.

The only studies concerned with the NSD discrimination learning of humans were conducted with highly test-sophisticated retardates. Zeaman and House (1962) and Honeck (1966) presented the retardates the NSD problem suggested by Spence (1952). In neither of the studies, however, were the Ss able to solve this problem. This failure may have been due to the fact that the stimulus combinations were presented in a random order from the beginning of testing, in contrast to the primate studies in which the Ss were first trained to criterion on each combination. On the other hand, the failure may have been due to the fact that complex multidimensional objects were used as stimulus elements. Such elements may be more difficult to maintain in memory because of their multidimensionality.

To the knowledge of the author no studies have been conducted which have compared and contrasted the SD and NSD problems. Such an endeavor would be theoretically significant since it would result in conclusions concerning differences in problem difficulty as a function of the type of stimulus (relational vs. compound) that must be responded to in order to solve the problem. Hence, one of the primary purposes of this study was to empirically determine whether there were any differences in difficulty between these two types of conditional problems. In order to accomplish this objective, a NSD problem was employed which was identical to the one suggested by Spence (1952) and used by Zeaman and House (1962) and Honeck (1966). Except for different stimulus elements, the only difference between the SD and NSD problems was that in the SD problem each of the three stimulus combinations was a different color. Thus, in the SD problem the correct stimulus element could be chosen by responding either to the compound of a stimulus element and a color or to the conditional relationship between two stimulus elements.

Since the SD problem did provide a dual basis on which to choose the correct stimulus element, another purpose of the study was to ascertain whether the Ss were responding to the compound stimulus or to the relational stimulus.

Also of major concern in the study was the question of differences in ability among normal humans from several grade levels to solve the SD and NSD problems. In addition to this interest in a developmental trend in problem solving, a final objective was to find a grade level at which the Ss had extreme difficulty in solving the NSD problem, with the expectation of being able to conduct future research with these Ss concerning the question of training in this type of problem-solving ability.

II
METHOD

SUBJECTS

The Ss were 150 students selected from 3 different school grades— 6th, 10th, and college sophomores (14th). The sixth-grade group was composed of 22 males and 20 females randomly selected from a group of 50 students at Marquette elementary school in Madison, all of whom had an IQ of 90 or more. In the tenth grade group were 21 males and 20 females randomly selected from a group of 78 volunteers from study hall classes at James Madison Memorial High School also in Madison. The college sophomores were 34 males and 33 females from introductory psychology classes at the University of Wisconsin who volunteered to take part in the study in order to obtain extra points toward their course grades. During the course of testing 6 Ss were dropped because of procedural errors, which reduced the number of Ss from the 6th, 10th, and 14th grades to 40, 40, and 64, respectively, with an equal number of males and females in each group.

There were 2 experimenters, 1 male and 1 female, both of whom had had extensive experience with the apparatus and experimental procedure prior to testing.

APPARATUS

A Kodak Carousel projector was used to present slides on a screen. Pictured on each slide were 2 geometric figures. When projected on the screen, the figures were situated horizontally in the center of the slide field 3 inches apart and were approximately 3 inches in height.

The S was seated approximately 4 feet from the screen at a small desk on which was situated a black response box 11 1/2 x 7 3/4 x 1 3/4 inches. Two small response buttons were located midway between the front and back edges on the top of the box, with the distance between them being 5 1/2 inches. On each presentation of a slide S indicated his choice of the right or left figure by pressing the right or left button. Immediate feedback was delivered in the form of a 2-tone door chime for a correct response and a buzzer for an incorrect response.

A Hunter Interval Timer controlled the time interval between the response and the onset of a new slide. At the termination of the post-feedback interval an impulse from the timer made the projector advance to a new slide automatically.

In order to generate the SD and NSD problems, six different figures and four different colors were needed. A homogeneous set of symmetrical geometric figures were selected (circle, cross, square, star, triangle, and "X") and four colors (blue, green, red, and yellow) were chosen on the basis of their discriminability after being photographed. Good experimental control of the stimuli would have required that the stimuli be balanced across the two problems. To be more explicit, not only would each of the figures and colors have to be used with each problem, but likewise each specific figure-figure combination of each color. For example, a triangle-square combination of each of the four colors would have to be used in both problems. Such an experimental procedure, however, was impractical because of the large number of unique stimuli which would have to have been constructed. Moreover, it seemed reasonable to assume that, for the particular Ss used in this study, the figure-color combinations were equally discriminable.

Hence, a weaker form of experimental control was used, i.e., randomization. Three figures and three colors were randomly assigned to the SD problem and three figures and one color were randomly assigned to the NSD problem, a procedure which randomly confounded the stimuli with the two types of problems.

The figures on the set of 60 slides used to present the SD problem were a circle, a cross, and a star. Only 2 of the figures, however, appeared on any individual slide. Within the set of 60 slides there were only 3 different slides, on which appeared the following combinations of the figures: circle-cross, star-circle, and cross-star. Both of the figures on each slide were the same color (blue, red, or yellow), with a given combination always being the same color (e.g., the circle-cross combination was always yellow). The figures on the slides used to present the NSD problem were a square, a triangle, and an "X", all of which were green. As with the first set of slides, only 2 figures appeared on each slide, and there were only 3 different slides on which appeared the following combinations of the figures: square-triangle, triangle-"X", and "X"-square. For both sets of slides there was an equal occurrence of each figure with the other 2 figures, resulting in 20 slides of each of the combinations. Figure 1 shows the figures for each problem and their arrangement on the slides.

DESIGN

The design was a 3 x 2 x 2 x 2 x 2 x 2 Latin square. The independent variables were grade level (6, 10, and 14), sex of experimenter, sex of subject, sequence of problem presentation (SD first vs. NSD first), order of presentation (problem 1 vs. problem 2), and problem type (SD vs. NSD). It should be noted at this point that this Latin square is a special type of Latin square with certain limitations not found in other Latin square designs (e.g., a 3 x 3 Latin

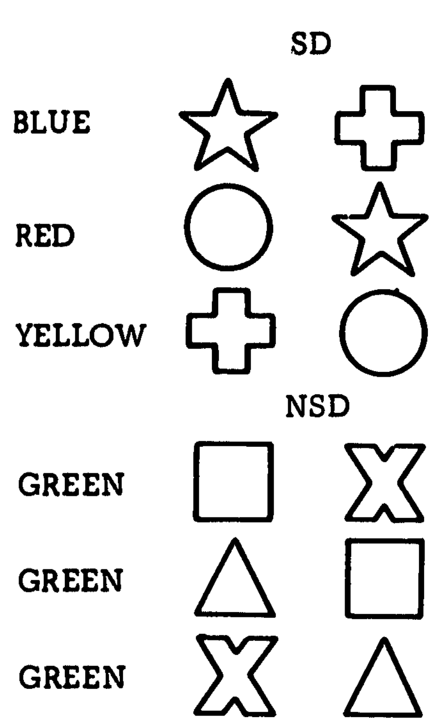

Figure 1. The arrangement of the stimulus elements on the slides for the SD and NSD problems

square). These limitations can best be understood by comparing the above design with a 3 x 2 x 2 x 2 x 2 factorial design with order omitted as an independent variable. Grant (1948) demonstrated that the sum of squares for the Order variable in this Latin square design would be identical to the sum of squares for the Sequence x Problem Type interaction in the factorial design. Thus, since there is complete confounding between these two factors, it is impossible to determine how much of the variance in the data can be attributed to each factor. Therefore, all analyses were performed on the basis of a 3 x 2 x 2 x 2 x 2 factorial design with the full realization that the analyses would not allow a definitive statement concerning transfer effects. The assumption was made that the verbalization data would provide evidence for an interpretation concerning any transfer effects.

PROCEDURE

All Ss were tested individually with the different groups being tested in the following order: 14, 10, and 6. Both of the problems were presented in a single session with half the Ss in each group receiving the SD problem first and half the NSD problem first. In addition, half of the Ss from each sex were tested by a female experimenter and half by a male experimenter.

The instruction for the 10th and 14th graders were presented by means of a tape recording. The Ss in these groups were given the following instructions:

Please listen carefully to the following instructions. If you have any questions after they have been given, please ask them. You are going to be given a problem to solve which will be presented to you by means of a series of slides. In the course of viewing these slides you will see 3 geometric figures—a square, a triangle, and an "X"—each of which will be green in color. On each individual slide, however, you will see only 2 of the 3 figures. One of the 2 figures has been designated by the experimenter as the correct figure and the other as the incorrect figure. The object of your task is to determine which of the 2 figures has been designated as the correct figure on each of the slides as it appears. For the first few slides, of course, your choice of the correct figure will simply be a guess. These guesses will then give you some basis for solving the problem. You are to indicate your choice of the correct figure by pressing one of the buttons on the black box in front of you. If on a particular slide you think that the figure on the right is the correct one, then you should press the button on the right, or, on the other hand, if you think the correct one is the figure on the left, then you should press the button on the left. The correctness or incorrectness of your choice will be indicated by a chime or a buzz. If you have chosen the correct figure, you will hear a chime, but if you have chosen the incorrect figure, you will hear a loud buzz. There is no time limit for making your choice. The next slide will not appear until approximately 5 seconds after you have pressed the button. Are there any questions?

You are going to be given another problem to solve involving a different series of slides. In the course of viewing these slides you will see 3 new geometric figures— a circle, a star, and a cross— which will be red, blue, or yellow in color. As was the case for the first series of slides, you will see only 2 of the 3 figures on each individual slide, with one figure having been designated the correct figure and the other the incorrect figure. The object of your task again is to determine which of the 2 figures on each of the slides has been designated the correct figure.

The instructions for the 6th graders were read aloud by E, and in some respects were different from those for the other 2 groups. The changes in the instructions were made on the assumption that the instructions for the other 2 groups were too abstract in nature for adequate comprehension by the 6th graders. The instructions for this group were as follows:

Please listen carefully to my instructions. I am going to show you some slides on this screen. On these slides you will see 3 figures which will look something like these 3 figures right here. But on each individual slide you will see only 2 of the figures. For example, if we pretend that these are the figures you are going to see, then on one of the slides you might see these 2 figures, but on the next slide you might see these figures and on another slide these figures. On each slide I have chosen one of the figures to be the right figure and the other one to be the wrong figure. What I want you to do is to pick out the right figure on each slide as it appears. Now then, you do not already know which figure is going to be the right one on each slide, do you? So what you must do is try to learn how to tell which figure is the right one. There is some way that you can tell which figure is the right figure. Take a look at the black box in front of you. You can tell me which figure you think is the right one by pressing one of the buttons on this box. Whenever you think the figure on this side is the right one, you should press this button and whenever you think the figure on this side is the right one, press this button. Each time you pick the right figure, a chime will ring when you press the button, but each time you pick the wrong figure, a buzzer will buzz. Press this button. If you hear that sound, you will know that you have picked the wrong figure.

The figures that I'm going to show you on the screen are a square, a triangle, and an "X", and they are all green in color. When each slide comes on the screen, take as long as you want to pick out the right figure. The next slide will not come on the screen until after you have pressed the button. Remember, what I want you to do is to learn how to pick out the right figure on each slide.

You are going to be shown another set of slides with different figures on them. You will see a circle, a cross, and a star which will be blue, red, or yellow. Again what I want you to do is to choose the right figure on each slide.

After the instructions were read, E asked S to describe what the experimental task involved. If S's response indicated any uncertainty, E clarified the instructions until S stated that he understood what was required of him.

In the presentation of slides for both problems, each of the 3 different slides appeared once in every 3 trials with the order of appearance in these 3 trials being randomly determined. The correct figure occurred equally often on the right and left in blocks of 6 trials with the sequence of correct positions also being randomly determined. At the beginning of each test day, the correct figure in one of the combinations from each set was randomly assigned. The correct figures in the other 2 combinations in each set were fixed by this assignment.

As the instructions implied, the experimental task was self-paced. After S had made his response, a 5-second interval elapsed before a new slide appeared, during which time the slide previously responded to remained on the screen. On both problems each S was presented slides until he had made 12 consecutive correct responses or until all 60 slides in a set had been shown. The chance probability of making 12 consecutive correct responses in a 60 trial series is less than .01. After testing on both problems had been completed, questionnaires were given to the 10th and 14th graders in order to ascertain the various strategies used by each S in attempting to solve the problem (see Appendix). The 6th graders were questioned by E instead of being given a questionnaire. The E began the questioning by asking S how he could tell which figure was the correct one and the verbal responses were recorded.

III
RESULTS

Three dependent measures were obtained—number of correct responses, trials to criterion, and verbal responses. Since an unequal number of Ss were tested in the three groups, all analyses of variance, except when noted otherwise, involved an unweighted means solution. Separate analyses of variance involving the complete set of independent variables were performed on the correct responses and trials to criterion data. The results from both overall analyses are presented in Table 1.

CORRECT RESPONSES

When an S reached the criterion of twelve consecutive correct responses, it was assumed that he would have made correct responses on all of the remaining unpresented trials. Thus, if an S reached criterion in fifteen trials, he was credited with correct responses for the remaining 45 trials, as well as for those made during the first fifteen trials. This total number of correct responses constituted the basic datum for the first analysis.

The analysis revealed a significant Grade Level effect ($F = 29.39$; $df = 2/120$; $p < .01$) and a greater difficulty with the NSD problem than with the SD problem ($F = 63.47$; $df = 1/120$; $p < .01$). None of the other main effects were significant. Figure 2 indicates the percent of correct responses on each of the problems as a function of grade level. Since the Grade Level x Problem Type interaction was not significant, it can be stated that at each grade level significantly more correct responses were made on the SD problem. Furthermore, subsequent tests showed that the 10th graders generally made more correct responses than the 6th graders ($t = 3.58$; $df = 120$; $p < .01$) and, in turn, the 14th graders performed better than the 10th graders ($t = 3.99$; $df = 120$; $p < .01$).

Because of the low percent of correct responses on the NSD problem (Figure 2) for the 6th and 10th grade groups (58% and 63%, respectively), separate analyses of the data from each group were made in order to determine if performance was above chance on each of the problems. The results indicated that for all three groups the mean number of correct responses on both problems was significantly above chance (all ts > 3.50; $df = 39$ for grades 6 and 10, 63 for grade 14; $p < .01$).

Although there was no Sequence effect in the overall analysis of variance, there was a significant Sequence x Problem Type interaction as depicted in Figure 3. In order to examine the nature of this interaction, separate analyses of variance were performed on the data for each problem. The results revealed that performance on both the SD and NSD problems was significantly better when each was the second problem presented ($F = 6.56, 13.27$; $df = 1/120$; $p < .05, < .01$, respectively). It is impossible to determine, however, whether this result was due to transfer from previous experience with a particular type of problem or to transfer due to previous experience with merely another problem, because of the complete confounding between these two types of transfer effects, as previously discussed.

Two other interactions were also significant—Subject Sex x Problem Type ($F = 12.22$; $df = 1/120$; $p < .01$) and Grade Level x Subject Sex x Problem Type ($F = 3.90$; $df = 2/120$; $p < .05$). Figure 4 clearly indicates that the major determinant of the latter interaction was the difference in performance between the males and females in the 10th grade group.

In the analysis of variance just presented there was a confounding due to the fact that half of the scores from each of the problems were influenced to some indeterminable extent by previous experiences with another problem. Hence, a second analysis of variance was performed on the most unequivocal data available—problem one data only. This analysis (Table 2) tended to agree with the main overall analysis. There was a significant Grade Level effect

Table 1

Analyses of variance of correct responses and trials to criterion data involving both problems one and two

Source	df	Correct Responses		Trials to Criterion	
		MS	F	MS	F
Grade	2	2686.93	29.39**	5641.39	27.90**
E Sex	1	.01		9.54	
S Sex	1	32.51		666.08	3.29
Sequence	1	32.31		4.29	
Gr x E	2	169.59	1.86	206.54	1.02
Gr x S	2	48.93		349.72	1.73
Gr x seq	2	104.63	1.14	357.01	1.77
E x S	1	3.57		2.92	
E x Seq	1	26.70		34.61	
S x Seq	1	67.86		11.67	
Gr x E x S	2	90.58		112.21	
Gr x E x Seq	2	96.72	1.06	136.38	
Gr x S x Seq	2	154.87	1.69	431.27	2.13
E x S x Seq	1	22.10		13.00	
Gr x E x S x Seq	2	1.17		62.45	
Error	120	91.42		202.19	
Problem	1	3950.92	63.47**	10476.34	59.15**
Gr x Prob	2	153.36	2.46	1337.59	7.55**
E x Prob	1	0.46		52.00	
S x Prob	1	760.48	12.22**	2694.67	15.21**
Seq x Prob	1	1464.80	23.53**	1510.72	8.53**
Gr x E x Prob	2	104.57	1.68	241.39	1.36
Gr x S x Prob	2	242.57	3.90*	501.39	2.83
Gr x Seq x Prob	2	7.52		25.81	
E x S x Prob	1	10.24		16.86	
E x Seq x Prob	1	7.20		278.88	1.57
S x Seq x Prob	1	110.20	1.77	2.25	
Gr x E x S x Prob	2	94.49	1.52	279.81	1.58
Gr x E x Seq x Prob	2	113.21	1.82	187.49	1.06
Gr x S x Seq x Prob	2	65.94	1.06	152.23	
E x S x Seq x Prob	1	0.98		43.43	
Gr x E x S x Seq x Prob	2	1.17		73.11	
Error	120	62.25		177.12	

* $p<.05$
**$p<.01$

(F = 16.94; df = 2/120; $p < .01$) with subsequent tests indicating a significant increase in the mean number of correct responses at each successively higher grade level (both $ts > 2.40$; $df = 120$; $p < .01$). The NSD problem again proved to be more difficult than the SD problem (F = 30.07; df = 1/120; $p < .01$). The data representing these main effects are presented in Figure 5. In contrast to the first analysis none of the interactions were significant. Thus, grade level and problem type are the major determinants of performance.

Each of the previous analyses considered data from both learners (reached criterion of twelve consecutive correct responses) and non-learners. In order to determine if there were any differences in the performance of learners among the three groups, an analysis of variance was performed on problem 1 data for learners only using a least squares solution. It was necessary to use this particular solution because the inequality in the number of learners among the three groups was not due to a random factor, as was the case in the previous analyses. Only two variables—Grade Level and Problem Type—were involved in this analysis. The results (Table 3) revealed significant differences among the grade levels (F = 6.94; df = 2/55;

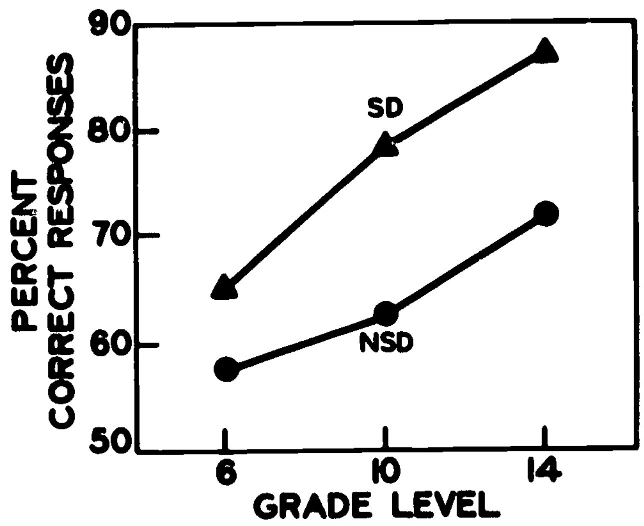

Fig. 2. Percent correct responses for the three grade levels on both the SD and NSD problems

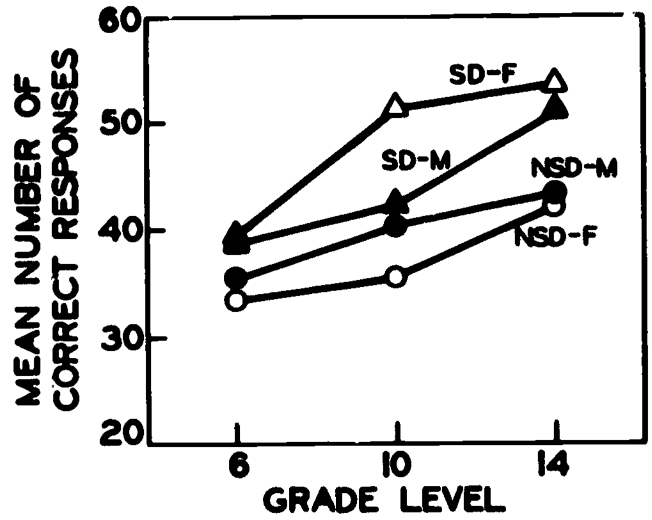

Fig. 4. Mean number of correct responses for males and females from each grade level on the SD and NSD problems

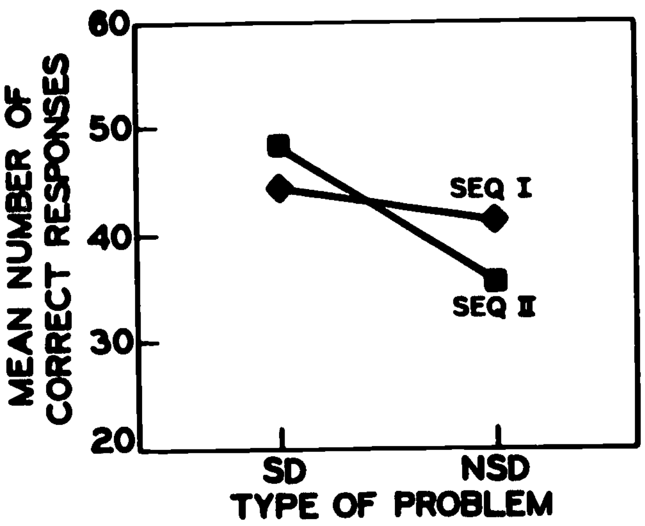

Fig. 3. Mean number of correct responses on the SD and NSD problems for each sequence of presentation

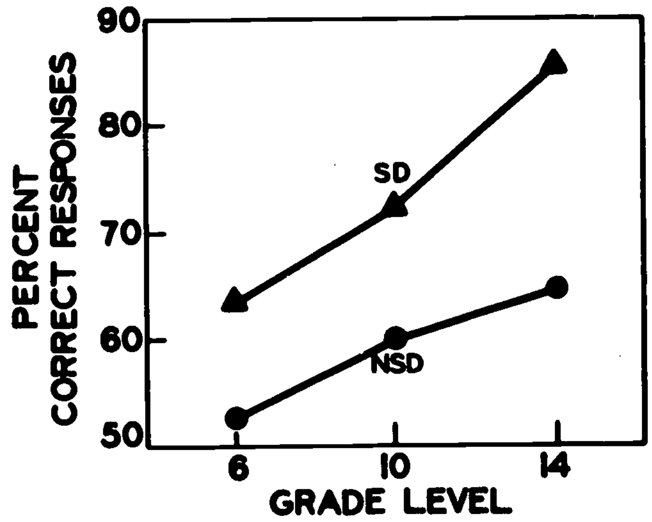

Fig. 5. Percent correct responses on the SD and NSD problems when each problem appeared first in the sequence of presentation

Table 2

Analyses of variance of correct responses and trials to criterion data for problem one only

Source	Correct Responses df	Correct Responses MS	Correct Responses F	Trials to Criterion MS	Trials to Criterion F
Grade	2	1323.73	16.94**	2523.80	15.43**
E Sex	1	3.30		92.64	
S Sex	1	131.21	1.68	295.43	1.81
Problem	1	2348.92	30.07**	5028.42	31.85**
Gr x E	2	76.44		188.12	1.15
Gr x S	2	87.65	1.12	438.09	2.68
Gr x Prob	2	54.96		1126.19	6.89**
E x S	1	4.15		11.92	
E x Prob	1	17.10		0.88	
S x Prob	1	187.00	2.39	1175.85	7.19**
Gr x E x S	2	111.26	1.42	161.11	
Gr x E x Prob	2	76.92		304.51	1.86
Gr x S x Prob	2	6.53		78.01	
E x S x Prob	1	1.13		29.73	
Gr x E x S x Prob	2	57.67	1.76	287.67	1.76
Error	120	78.12		163.55	

**p<.01

Table 3

Analyses of variance of correct responses and trials to criterion data for learners only

Source	Correct Responses df	MS	F	Trials to Criterion MS	F
Grade	2	162.3	6.94**	776.16	5.06**
Problem	1	350.91	14.98**	1825.59	11.91**
Gr x Prob	2	4.12	0.18	55.61	0.36
Error	55	23.43		153.38	

**p<.01

$p < .01$) and between the two types of problems ($F = 14.98$; $df = 1/55$; $p < .01$). The percent of correct responses on each of the problems as a function of grade level is shown in Figure 6. The mean number of correct responses for the SD problem was greater than that for the NSD problem. An examination of the differences among the grade levels showed that the 10th graders made significantly more correct responses than the 6th graders ($t = 2.17$; $df = 55$; $p < .025$), but the 10th graders did not, in turn, differ significantly from the 14th graders ($t = 1.38$; $df = 55$). These results then are generally consistent with those obtained from the analysis involving both learners and nonlearners.

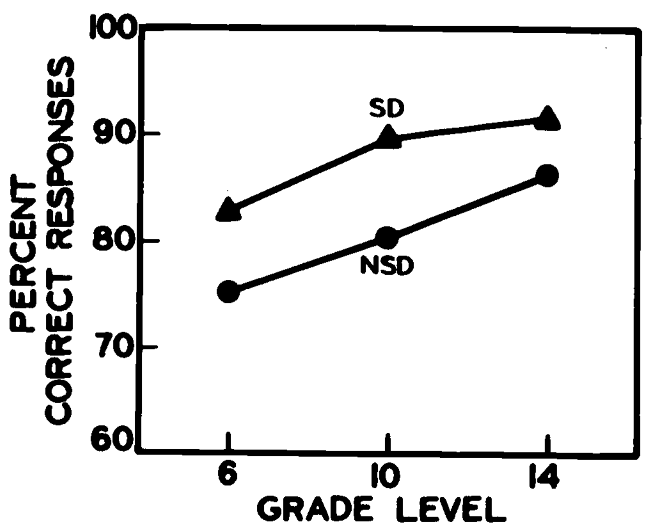

Fig. 6. Percent correct responses for learners only on the SD and NSD problems when each problem appeared first in the sequence of presentation

TRIALS TO CRITERION

The results from an analysis of the trials to criterion data (Table 1)-tend to be consistent with the results from the analysis of the correct responses data. One minor difference between the two sets of results was the significant Grade Level x Problem Type interaction (Figure 7) in the trials to criterion analysis. A subsequent analysis of this interaction revealed a significant difference between the problems for both the 10th and 14th graders (both $ts > 4.30$; $df = 120$; $p < .01$), but no significant difference for the 6th graders ($t = 1.48$; $df = 120$). In order to determine if there was a significant decrease in trials to criterion at successively higher grade levels, separate analyses of variance were performed on the data from each problem. Subsequent tests, made on the basis of significant results obtained in these analyses, indicated that on the SD problem, there were significant differences between each of the grade levels (all $ts > 3.30$; $df = 120$; $p < .01$). On the NSD problem, however, there was no significant difference between the 6th and 10th graders ($t = 1.04$; $df = 120$).

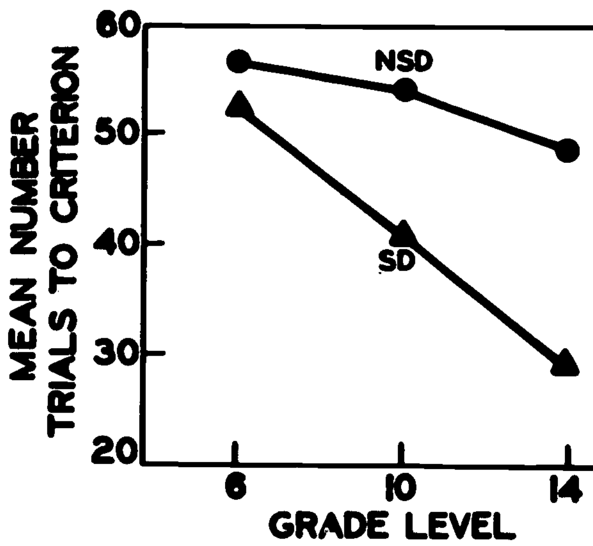

Fig. 7. Mean number of trials to criterion for the three grade levels on both the SD and NSD problems

The analysis of variance involving problem 1 data only (Table 2) also showed a decrease in the number of trials to criterion among the grade levels ($F = 15.43$; $df = 2/120$; $p < .01$) and a significant difference in the mean number of trials to criterion for the two problems (F =

31.85; df = 1/120; p < .01). As with the overall analysis of the trials to criterion data, the interaction between these two factors was significant. With only one exception the results from subsequent tests corroborated those obtained from the subsequent tests of this interaction in the overall analysis. The only significant difference in performance among the three grade levels on the NSD problem was between the 6th and 14th graders (t = 1.83; df = 60; $p < .05$).

The learners-only analysis of variances for this measure also indicated a Grade Level effect (F = 5.06; df = 2/55; $p < .01$) and fewer trials to criterion for the SD problem (F = 11.91; df = 1/55; $p < .01$). The interaction between these two factors was not significant. An analysis of the Grade Level effect indicated a significant difference between 6th and 10th graders (t = 1.89; df = 55; $p < .05$), but no such differences between the 10th and 14th graders ($t < 1$; df = 55).

In conclusion, it can be stated that the results from the various analyses of the trials to criterion data clearly indicate a difference in difficulty between the two types of problems, but the results do not clearly substantiate a significant difference in performance between each of the adjacent grade levels on each of the problems.

VERBAL RESPONSES

As previously stated, there were two possible stimulus relationships to which an S could respond which would enable him to solve the SD problem: 1) a compound of a color and a single figure, or 2) the conditional relationship between two figures. Hence, either of two verbalizations of the solution for this problem was considered correct. Examples of verbalized solutions reflecting a response to the figure-color relationship which were considered adequate are the following: "red star, yellow circle, and blue cross" and "a different figure was correct with each color." Adequate verbalizations reflecting a response to the figure-figure relationship were "circle>star, star>cross, and cross>circle" and "in each combination one figure was always correct." These latter verbalizations were considered adequate for the NSD problem also, since the only means for solving this problem was by responding to a figure-figure relationship. If the explanations of the correct solutions written on the questionnaire were ambiguous, the S was asked to clarify his written statement. If his verbalized explanation was similar to the above explanations, he was considered a correct verbalizer also.

As Table 4 indicates, the percent of correct verbalizers increases at each successively higher grade level and is higher for the SD problem than for the NSD problem. Table 5 shows the percentage of correct verbalizers on the SD problem that responded to each of the two types of relationships as a function of the order of presentation. When the SD problem was given first, there was a much greater tendency to respond to the figure-color relationship, but when it came second the tendency to respond to the conditional relationship between the figures increased markedly.

Finally, it is important to note that in no instances did a verbal report indicate that a particular stimulus combination made one problem easier (or harder) than the other problem. Thus the confounding of stimuli with problems did not appear to be of any consequence in the performance of any of these subjects.

Table 4

Percent correct verbalizers from each grade level on both the SD and NSD problems

Problem	Grade 6	Grade 10	Grade 14
SD	30.00	70.00	84.37
NSD	30.00	40.00	59.38

Table 5

Percent of correct verbalizers responding to either the compound or conditional relationship in the SD problem in both orders of presentation

	6		10		14	
	Comp	Cond	Comp	Cond	Comp	Cond
First	80.00	20.00	88.89	11.11	80.00	20.00
Second	16.67	83.33	53.33	46.67	40.00	60.00

IV
DISCUSSION

For the sake of clarity, the differences between the structures of the two problems will be briefly reconsidered before attempting to interpret the results. In the SD problem the Ss could have solved the problem by responding to either of two stimulus relationships. First, they could have chosen the correct figure on each slide by responding to a compound cue composed of a figure in combination with a color (e.g., blue star). By responding on this basis, the Ss would not have to attend to the other figure on the same slide. As a consequence, they may not have been aware that each of the figures appeared in combination with both of the other figures. Second, the Ss could have responded to a conditional relationship between the two figures on each slide. Such a response would be based on the knowledge that the correctness of a given figure was determined by the other figure with which it was paired. In the NSD problem, however, the Ss could have solved the problem only by responding to the conditional relationship between the two figures on each slide, since there was no variation in color involved in the problem.

The assumed sophistication of these Ss with respect to the stimuli used, the lack of any report of differential discriminability among the stimulus combinations per se, and the random assignment of stimuli all suggest that any difference in performance on the two problems is most reasonably attributable to the inherent structure of the problems and not to an artifact of the particular stimuli associated with a given problem. The following discussion assumes, therefore, that the differences between the two problems is due to differences in problem structure.

The results concerning differences in problem difficulty were rather straight-forward. The NSD problem was always more difficult than the SD problem, irrespective of what particular set of data was considered (problem 1 only, both problem 1 and 2, or learners-only). Although the SD problem could have been solved by responding to the conditional relationships between the figures (as is required in the NSD problem), the difference in problem difficulty strongly suggests, on the contrary, that the Ss were solving the SD problem by responding to the compound cue involving a single colored figure. The results from the verbalization data of learner-only presented in Table 5 provide supporting evidence that at least on the critical first presentation of the SD problem, the Ss responded primarily to the compound cue in solving that problem. The fact that there was a decrease in responding to this cue when the SD problem was presented second suggests that there was definite transfer from the previous specific experience with the NSD problem.

One possible explanation for these results is provided by the notion of a hierarchy of response tendencies implied by Spence (1952) in his discussion of effective cues in discrimination problems. As previously stated, Spence hypothesized that Ss would respond to a conditional relationship between stimulus elements only if the problem were structured such that the individual elements (e.g., form) or compound cues (e.g., form + position) were not differentially reinforced. Thus, in the SD problem, Spence would have predicted no response to the conditional relationship between figures, since a compound cue (figure + color) was consistently reinforced, and hence constituted a basis for solution of the problem. In his statement concerning differential response tendencies, Spence also implied that even if the discrimination problem were structured such that a response to a conditional relationship was required for correct solution, the Ss would first respond to independent stimulus elements or compound cues. Hence, the NSD problem should be more difficult than the SD problem.

To predict a difference in difficulty between the SD and NSD problems on the basis of a hierarchy of response tendencies, however,

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does not mean that one has advanced an explanation for the difference. In order to achieve an adequate explanation, one must go beyond the notion of a hierarchy and explain why one particular response tendency is lower in the hierarchy than another response. In an effort to explain the ordering of response tendencies, the author proposes that there is no constant hierarchy of response tendencies which is effective across all types of discrimination problems. Rather, it is assumed that the hierarchy varies from situation to situation and is mainly determined by two factors— the specific structure of the discrimination problem and the nature of the instructions given.

In support of the notion that the structure of the problem has an important influence on response tendencies, Bitterman (1952) was able to devise a two-choice discrimination problem on which the Ss responded to the total stimulus configuration rather than to independent stimulus elements within the configurations, even though independent elements were differentially reinforced. Two different combinations of stimulus elements were used— blocks with narrow (N) or wide (W) stripes and light (L) or dark (D) blocks. During the training phase of the study, one block in each combination was always correct and always presented in the same position (right or left), with the correct block in each combination occurring in opposite positions. The combinations were presented in a random sequence. For example:

  +
W N
+
L D
+
L D
  +
W N

After criterion had been reached on these combinations, the positions of the previously correct blocks were randomly switched during the testing phase. For example, a sequence of trials might have been as follows:

  +
D L
+
N W
  +
W N
+
L D

If the Ss were responding to a consistently reinforced stimulus element, switching the position of the correct element should not have resulted in an increase in incorrect responses. On the other hand, if the Ss were responding to two different stimulus configurations, one involving striped blocks and the other blocks differing in brightness level, they should have continued to make the same directional response to the configurations that was learned during the training phase, even though the positions of the individual blocks were changed from trial to trial. The results revealed that the Ss continued to make the same directional response, thus indicating that they were responding to configurations of elements rather than to independent elements.

In the present study the structural aspect of the SD problem that is particularly important is the extraneous cue of changing color. It is assumed that this structural aspect of the SD problem exerts a considerable influence on the response tendencies of the Ss, since it is, with the exception of the changing position of the figures, the most salient of the extraneous cues.

Since human Ss were used in this study, it is also assumed that the specific set of instructions used determined to some extent the ordering of the response tendencies. In other words, the instructions provide the S with a set to attend to certain cues as opposed to others. In this study, for example, the emphasis in the instructions was placed especially on choosing the correct figure on each slide. As a consequence, the Ss may have been concerned primarily with determining whether there was some characteristic about each figure, such as its size, position, or color, which would make it correct. Therefore, since the SD problem can be solved on the basis of this initial response tendency to individual characteristics, it should be easier to solve than the NSD problem which cannot be solved on this basis.

It seems entirely feasible to explain the results, however, without having to postulate a hierarchy of response tendencies. The Ss may have responded to the conditional relationship between figures in either the SD or NSD problems during the early part of their presentation. However, because of encoding and/or memory difficulties, the Ss may have abandoned responding on this basis.

By encoding difficulties, the author means that the Ss found it difficult to devise verbal mediational responses by means of which to remember when a given figure was correct. For example, the Ss may have found it difficult to devise a response such as "if □ and △, then □ ; if △ and X , then △ ; if X and □ , then X ." In contrast to this mediational response, the mediational response for remembering the correct figure in the SD problem would involve nothing more than naming a stimulus compound (e.g., blue star, red circle, and yellow cross).

Even if the Ss were able to produce useful mediational responses, they may have found it quite difficult to retain these responses. The difficulty may have resulted from the fact that during the presentation of the problems a new combination of figures appeared on each trial. Only in a few instances did the same combination appear on successive trials, and never more than twice in succession. Thus, there was much interference generated from trial to trial. Support for this notion of interference due to the sequence of the presentation of stimulus combinations is provided by Lubker (1967) who used an SD conditional discrimination problem involving only two different stimulus combinations. The results revealed that performance was significantly better when each combination was presented in blocks of 5 trials as opposed to when they were presented in a random sequence.

As to which, if either, of the explanations discussed above is more adequate in accounting for the results, only further experimentation will be able to indicate. It is the opinion of the author that neither of the explanations in itself will be shown to be adequate. Rather, it is assumed that the factors involved in each explanation will have differential effects on performance on the two types of problems used in this study.

The results also indicated that in general there appeared to be a developmental trend in problem-solving ability, especially with the SD problem. The trend was not so salient for the NSD problem, since in some instances there were no statistically significant differences between the 6th and 10th graders on this problem.

Several explanations can be advanced to account for this result. One of the most feasible explanations for the developmental trend is the differential amount of formal problem-solving experience among the three groups obtained in various math and science courses in school. Presumably, the experiences derived from this sort of training would have some generality so that they would have some influence on the manner in which the S approached a problem-solving task.

There are, however, other characteristics on which the three groups are not comparable. First of all, there may have been differences in the comprehension of the instructions among the groups. Much care, however, was taken in the presentation of the instructions to minimize this possibility. Second, and possibly of much significance, is the likelihood that the three groups were not comparable with respect to the range of IQ scores represented in each group. Although IQ scores were not available for the college sophomores, it is highly probable that the mean IQ for this group was significantly higher than that for the other two groups. Lack of comparability on this last factor makes it difficult to interpret the apparent developmental trend.

One other important matter that should be considered is the relatively poor level of performance of the sixth graders (Figure 2), especially on the NSD problem. Although the percent of correct responses for this group on this problem was significantly above chance, it is the opinion of the author that this level of performance indicates that the sixth graders have much difficulty solving problems of this type.

Several explanations for this deficiency are feasible. First, the sixth graders may be, in general, poor problem solvers. That is, these Ss do not make efficient use of feedback in solving problems. Feedback acts as a signal to indicate a correct or incorrect response, but it does not indicate to the S whether or not he should continue or change his problem-solving strategy. On the basis of an examination of some of the verbal reports, the author noticed that some of the Ss tended to persevere on only one or two strategies, especially if they resulted in a high number of correct responses. This observation indicates that some of the Ss may have been only trying to make correct responses rather than to solve the problem. Second, the poor performance may have been due to the fact that the strategy of responding to conditional relationships between stimulus elements is not readily available to these Ss. This is not to say that they cannot and do not make such conditional responses in some situations, but that in certain problem-solving situations these responses are much less probable than other responses. Future research is needed to indicate the exact nature of the deficit in performance for this group of Ss.

In summary, the results indicate that the NSD problem is definitely more difficult than the SD problem. Although an explanation for this difference in difficulty cannot be derived from this study, the author proposes that instructional set and the structure of the problems are the major factors influencing performance. Although interpretations with respect to a developmental trend in problem-solving ability must be cautious, the data does give some support to the notion of a developmental trend.

APPENDIX
QUESTIONNAIRE FOR TENTH AND FOURTEENTH GRADERS

1. Were the instructions clear?

2. Explain as clearly as possible the different strategies that you used in trying to determine which figure was correct in the first series of slides which involved only green figures (□ × △).

3. Explain, as above, the strategies you used in the second series of slides which involved red, blue, and yellow figures (○ + ☆).

1. Were the instructions clear?

2. Explain as clearly as possible the different strategies that you used in trying to determine which figure was correct in the first series of slides which involved red, blue, and yellow figures (○ + ☆).

3. Explain, as above, the strategies you used in the second series of slides which involved only the green figures (□ × △).

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TITLE

A developmental study of sign-differentiated and non-sign-differentiated conditional discrimination learning

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ABSTRACT

The ability to make relational discriminations, i.e., to solve problems by responding to the relationships between cues rather than to the absolute properties of individual cues is examined. The laboratory analogy of this type of problem is referred to as a conditional discrimination problem. Mr. Grogg first empirically demonstrates the difference between a sign-differentiated (SD) and a non-sign-differentiated (NSD) conditional discrimination problem, the former not necessarily requiring a relational rule for solution but the latter necessarily involving true relational learning. Sec...ly, by testing 6th graders, 10th graders and college sophomores, data is provided concerning the developing ability to solve such problems.

The results indicated that at each grade level the NSD problem was more difficult than the SD problem. Also revealed was a monotonic developmental trend in conditional problem-solving ability. The results were interpreted in terms of 1) a hierachy of response tendencies, and 2) a differential cognitive requirement.