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Multiple-Cue Learning in Children[1]

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Children's ability to use multiple sources of information in making judgments was investigated using the Brunswik lens model. Approximately equal numbers of boys and girls (144 in all) from third, fifth, seventh, and ninth grades were asked to use the color, the form, and the border of each of 128 stimuli to determine how far to move a lever across a slot, after which they were shown how far they should have moved the lever. The correct distance was determined by the formula $2C_1 + 1.5C_2 + C_3 = \text{LD}$, where the *C*s stand for the three cues (color, form, and border) and LD, lever displacement. The results indicated that (*a*) the children were able to use multiple cues simultaneously in making judgments, (*b*) there was a general tendency for performance to improve with age, (*c*) there was a tendency (increasing over trial blocks) for children to use the cues in the correct order (most valid, intermediately valid, least valid), (*d*) children tended to rely primarily on only two cues in making their judgments, and (*e*) boys tended to respond to the most valid cue more than did girls.

Research with adults (Hammond, 1966; Smedslund, 1955) has indicated that adults are able to use multiple cues in problem solving. The purpose of this research is to discover the age at which children begin to use multiple cues in problem solving.

Most research with children has concerned itself with one cue (or dimension) learning at a time. Eimas (1965), however, was concerned with children's ability to use compounds (as opposed to components) in discrimination learning. Components were described as solitary aspects of the stimulus, such as "black" or "triangle," while compounds were defined as the union of such aspects, such as "black triangle." To discover whether or not kindergarten children used such compounds, Eimas designed the test trials of a discrimination-learning experiment so that either a positive (reinforced) or a negative (nonreinforced) compound or the components (not in a compound) were present. Comparing across the three groups (positive compound, negative compound, components), he discovered that all subjects showed signs of using the compounds, that, overall, compounds were used more than components, and that positive compounds were used more than negative compounds. Eimas's research has given support to the idea that young children are able to attend to more than one dimension at a time, and that this attention may improve their learning.

A second source of information concerning children's awareness of multiple dimensions has come from the research of Osler and Kofsky (1965, 1966) on the role of stimulus uncertainty in concept learning. Uncertainty was determined by the number of irrelevant dimensions present in the stimulus array; more irrelevant dimensions

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meant more uncertainty. As the children increased in age from 4 to 11 years they were able to solve problems with increasingly greater uncertainty levels. Osler and Kofsky reported that the children also responded in a systematic fashion to the irrelevant dimensions, implying that the children were aware of more than just the relevant dimension of the stimulus array.

If these results may be related to the case where all the dimensions are relevant to the solution of the problem, it would appear that 10- or 11-year-olds, and possibly some younger children, might meet with success in a task where multiple dimensions were relevant, since there appears to be considerable evidence that children are aware of multiple dimensions whether or not they are necessary to solution. The specific hypothesis tested by this research is that children are able to attend to multiple cues simultaneously and are able to use the information contained in these cues. In order to test this hypothesis, a multiple-cue-learning task, which was derived from Brunswik's lens model, was employed.

Ecological validities (correlations which describe the relationship between the external environment and the sensory cues) were set up between each of the three simultaneously presented cue dimensions and the distal variable, lever displacement, whose magnitude varied with the size of the specific values of each of the three cues. The cue-utilization coefficients (correlation between each cue and the child's response) and achievement (correlation between correct lever displacement and the child's response) were computed for blocks of trials throughout learning.

Following Piaget's theory that the type of abstract reasoning necessary for success at this task does not occur until the period of formal operations, it was expected that children older than 11 years of age would use all the cues and that their cue-utilization coefficients would approximately match the experimentally established ecological validities. It was also expected that children under 11 years of age would not be able to successfully use all three cues, but rather would depend on the cue with the highest ecological validity for their responses.

Method

Subjects

One hundred and forty-four middle- and working-class children from the third, fifth, seventh, and ninth grades (36 at each grade level) of the Danville, Illinois, public school system were the subjects for this experiment. The children were a racially mixed group at all age levels and fell within the average range of intellectual ability. There were approximately equal numbers of boys and girls. (There were equal numbers of boys and girls in every grade but the third grade which had 13 girls and 23 boys.)

Apparatus

The stimuli for the experiment, 64 colored geometrical forms with a border around each form, were photographed on 35-millimeter slides. All possible combinations of the three dimensions (color, form, and border) were used and were varied from slide to slide. Each color was assigned a value, as was each form and border. Red was assigned a value of 1; yellow, 2; green, 3; and blue, 4. A circle was assigned a value of 1; a square, 2; a triangle, 3; and a T, 4. The border around each figure was given a value as follows: dots, 1; dashes, 2; ovals, 3; and Xs, 4.

The response apparatus displayed a stimulus slide. Below the stimulus display was located a slot and a lever. There were two rows of 14 lights each, one directly above the slot and one directly below. The child responded by moving the lever from its resting position at the left, to a new position under one of the lights. As he moved the lever past them, the lights in the upper row came on to show the child how far he had moved the lever. After the child removed his hand from the lever, the bottom row of lights came on to show him the correct position for the lever. The experimenter manipulated the stimuli and recorded the children's responses from alongside the apparatus. Latency of responding was measured by a timer that started when the stimulus display appeared on the screen, and stopped when the child moved the lever from the resting position.

Procedure

Children were brought from the classroom to the experimental trailer by the experimenter, who explained that they were going to play a game. Children were told that they would see a picture which would tell them how far to move the lever. In order to be sure that the children understood the instructions, 12 pretraining trials were given immediately preceding the actual task. Three "junk" pictures (a baby, a boy, and a man) were presented in the same fashion as the geometric forms. After each trial children were given feedback as to the correct distance the lever should have been moved. After the pretraining trials, the children were reminded to notice the things that changed from picture to picture (the shape of the figure, the color of the figure, and the kind of border around the figure) and to use these clues to tell where to move the lever. Children were told that for a while the bottom lights would not come on, and that the experimenter would announce when the bottom lights would again provide feedback.

There were 128 trials (each of the 64 unique stimuli was seen twice). The child viewed each slide and then responded by moving the lever at his own pace. The first block of 16 trials occurred without feedback in order to assess individual preferences for the three cues. After the first block of trials a feedback procedure was employed. After the child removed his hand from the response lever, the lights below the slot came on to show the distance through the slot which was correct for that trial. The series of 128 trials was composed of eight blocks of 16 trials each. Each of the four values of each cue dimension appeared equally often in combination with each of the other two cues. Each block was based on one of eight different Latin squares (Fisher & Yates, 1948), thus providing zero correlation between any two cues within each block.

The cues were related to the lever displacement (LD) in the following manner: $LD = 2(C_1) + 1.5(C_2) + 1(C_3)$, where the Cs stand for the three cues (color, form, border). Since each cue varied in value from 1 to 4, lever displacement ranged from 4.5 (when all cue values were 1) to 18 (when all cue values were 4). This relationship may be expressed in terms of correlations. Since the square of a correlation corresponds to the proportion of the total variance explained, it was possible to calculate the correlation coefficient for a cue by the equation $(2r)^2 + (1.5r)^2 + r^2 = 1.00$, therefore $r = .371$. Thus the ecological validities for the three cues were .37, .56, and .74, respectively.

Design

The design was a 6 × 4 × 2 factorial with six counterbalancing conditions, four ages of children, and two sexes of children. There were three children of each sex in each condition for Grades 5, 7, and 9. For the third grade there were two girls and four boys in conditions color-form-border, color-border-form, form-color-border, form-border-color, and border-color-form, and three girls and three boys in condition border-form-color. The six conditions were derived from counterbalancing cue type (color, form, border) and ecological validities. For ease of later reference, the six conditions were coded according to decreasing ecological validity. Thus condition form-border-color has form with the highest ecological validity (.74), border next at .56, and color least at .37. All children, regardless of condition, had the same stimuli in the same order for all 128 trials of the experiment. The only differences among the six conditions were in what constituted a correct response.

Results

The 128 trials of the task were divided into eight blocks of 16 trials. For each block of trials, Pearson product-moment correlation coefficients were calculated between children's responses for each trial block and the correct answers. This correlation has been labeled children's achievement at the task. Pearson product-moment correlation coefficients were also calculated between children's responses in each trial block and the values of the most valid cue, between children's responses and the values of the intermediate cue, and between children's responses and the values of the least valid cue. These correlations have been labeled children's cue utilization for each of the three cues. The correlations were then transformed to Fisher's Z scores for further analysis.

Analysis of Variance of Achievement

A 6 (Condition) × 4 (Grade) × 8 (Block) analysis of variance was performed on the achievement Z scores. This analysis revealed a significant grade effect ($F = 2.85$, $df = 3/120$, $p < .05$) which showed that children's achievement scores increased with grade in school. The mean achievement scores for each grade were third, .116; fifth, .150; seventh, .208; and ninth, .220. Achievement scores also increased significantly over trial blocks ($F = 23.187$, $df = 7/840$, $p < .001$). The increase from block to block was not consistent as can be seen from the following means: Block 1 = .043, Block 2 = .017, Block 3 = .203, Block 4 = .156, Block 5 = .175, Block 6 = .170, Block 7 = .349, and Block 8 = .286.

Analysis of Variance of Cue-Utilization Coefficients

To investigate children's cue utilization of the three cue weightings a 6 (Condition) × 4 (Grade) × 2 (Sex) × 3 (Cue Weightings) × 8 (Blocks) analysis of variance was performed on the Z transformations of children's cue-utilization coefficients. This analysis revealed a significant effect due to condition ($F = 2.61$, $df = 5/96$, $p < .05$). The border-form-color condition had the highest average cue utilization (.155) followed by form-color-border (.120), color-form-border (.114), form-border-color (.090), border-color-form (.081), and finally color-form-border (.056). This result, coupled with the fact that there was no main effect of cue weighting, implied that certain physical characteristics of the cues had a salience for children beyond that experimentally imposed by the cue weightings. A significant effect of cue weighting would have indicated that the children had learned the ecological validities of the cues without regard to other aspects of the cues. There was a main effect of grade ($F = 2.69$, $df = 3/96$, $p < .05$), reflecting the fact that the average of the cue-utilization coefficients for all the cues increased with grade (third = .068, fifth = .093, seventh = .118, and ninth = .133). Children's average cue utilization showed a significant increase over trial blocks ($F = 26.77$, $df = 7/672$, $p < .001$), but the increase over blocks was also significantly different for each cue weighting ($F = 2.58$, $df = 14/1344$, $p < .001$). Children's cue utilizations over trials increased the most for the most valid cue and least for the least valid cue.

The interaction of condition with cue weighting ($F = 2.75$, $df = 10/192$, $p < .001$) provided further support for the hypothesis that the salience of the cues interfered with children learning the correct weightings of the cues. For conditions form-color-border and form-border-color the most valid cue was also the cue with the highest cue utilization. The cue utilizations of the intermediate- and low-validity cues were approximately equal, and quite low compared to the most valid cue. Children in conditions color-form-border and border-form-color had the highest utilization for the cue of intermediate validity. In condition color-form-border, the most valid cue had the second highest cue utilization, while in condition border-form-color it was the least valid cue which had the second highest cue utilization. In condition border-color-form the order of the cue utilization was the least valid cue (highest cue utilization) followed by the most valid cue, and finally the intermediate cue, and for condition color-border-form the order was most valid, least valid, and intermediate. Thus, in all conditions except color-border-form the cue which had the highest cue utilization was the form cue. There also was a tendency for color to be used more than border, but this was not as clear as the effect of form.

Cue weighting interacted significantly with sex ($F = 3.05$, $df = 2/192$, $p < .05$), which revealed that boys tended to have the highest cue utilization for the most valid cue (.161) with the intermediate- and low-validity cues about equal (.072 and .063, respectively). Girls, however, tended to have higher cue utilization coefficients for the cue of intermediate validity (.122), with high- and low-validity cues used to a lesser, approximately equal extent (.102 and .096, respectively). Condition also interacted significantly with sex and cue weighting ($F = 1.92$, $df = 10/192$, $p < .05$). The sex difference may have been the result of girls' greater use of both form and color cues when they were not the most valid. Boys also appeared to be influenced by form, but they seemed to be more influenced by the cue validities than were the girls.

The Condition × Cue Weighting × Blocks interaction ($F = 2.82$, $df = 70/1{,}344$ $p < .001$) appeared to be the result of the salience of the physical characteristics of the cues conflicting with the experimentally imposed cue weightings. As illustrated in Figure 1, in all but the color-form-border condition children showed greater use of the form cue, even though it was the most valid cue only in conditions form-color-border and form-border-color. Tukey comparisons (Winer, 1962) of the cue-utilization coefficients for Trials 2 and 8 for each validity level in each condition showed a significant increase in cue use for the color cue and the form cue in all six conditions. However, the border cue showed a significant increase only in the border-color-form condition, and a drop in the color-form-border and form-color-border conditions, while showing no significant change in the other three conditions. The inconsistency in children's responding over trials may have been the result of children's attempting to use different weighted combinations of the cues.

Also displayed in Figure 1 are the children's achievement correlations for the various conditions over blocks. There was no

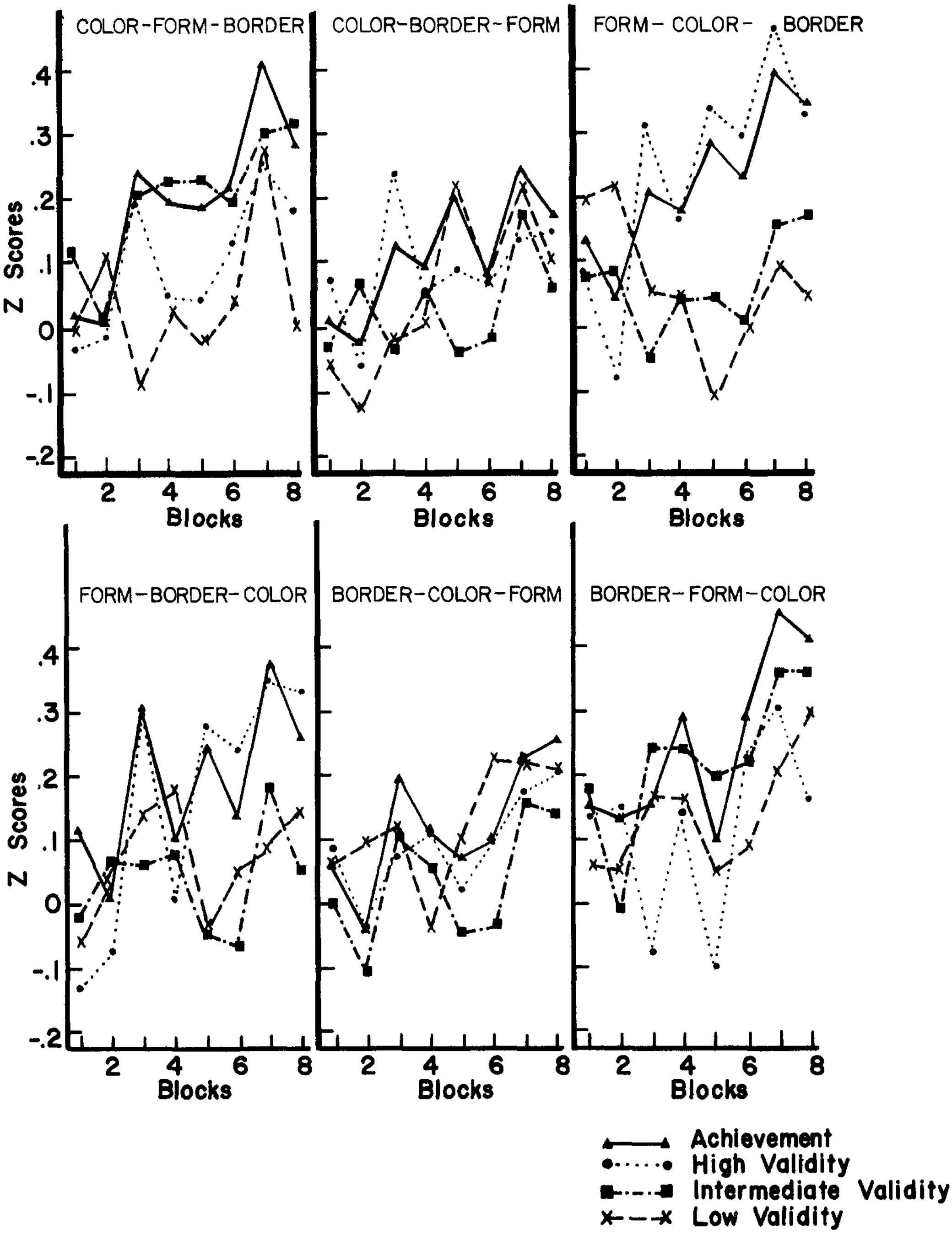

Fig. 1. Condition × Cue weighting × Blocks interaction for cue-utilization Z scores and achievement scores.

significant interaction among these variables when achievement was the dependent variable. Apparently the salience of the cues did not affect children's achievement. When one cue had a very high cue utilization, as form did when it was most valid, there was a corresponding drop in the use of the other cues.

Three-Mode Factor Analysis

In order to shed some light on children's patterns of responding, a three-mode factor analysis was performed. The three modes of the analysis were individuals, trial blocks, and the three cue weightings. Since the cue weightings could not be represented by any fewer dimensions (they were uncorrelated over blocks), interest was centered on the modes representing trial blocks and individuals.

The data used in the analysis were the covariances of children's responses with each of the cue weightings over the eight trial blocks. With the data arranged in a matrix, X, of 8 rows (trial blocks) and 432 columns (all Cue $\times$ Individual combinations) it was possible to obtain an XX' matrix for blocks (see Tucker, 1963, 1964). By inspection of the characteristic roots of this matrix it was decided to retain only the first dimension. This reduced the trial block mode to one dimension, which was interpreted to mean that children generally improved their cue utilization over trials, but did not shift the order of their cue use. With the data arranged in a matrix, X, of 144 rows (individuals) and 24 columns (all Cue $\times$ Trial Block combinations), it was possible to obtain an XX' matrix for individuals. By inspection of the characteristic roots of the matrix it was decided to retain the first two dimensions. The location of children on those two dimensions has been plotted in Figure 2.

The interpretation of these dimensions was aided by examination of the three-mode core matrix which may be considered as Idealized Individuals $\times$ Idealized Trials $\times$ Cues. The first dimension primarily represented use of the most valid cue, as children loading highly on Dimension I weighted the cues in a proportion approximately as follows: most valid = 741.08, intermediate = 93.94, and least valid = 47.78. Dimension II, on the other hand, may be interpreted to represent use of the intermediate cue, for children weighted the cues in approximately the following proportions: most valid cue = −52.23, intermediate cue = 347.55, and least valid cue = 100.47.

Multivariate Analysis of Variance

To determine if individual differences were also related to the experimental varia-

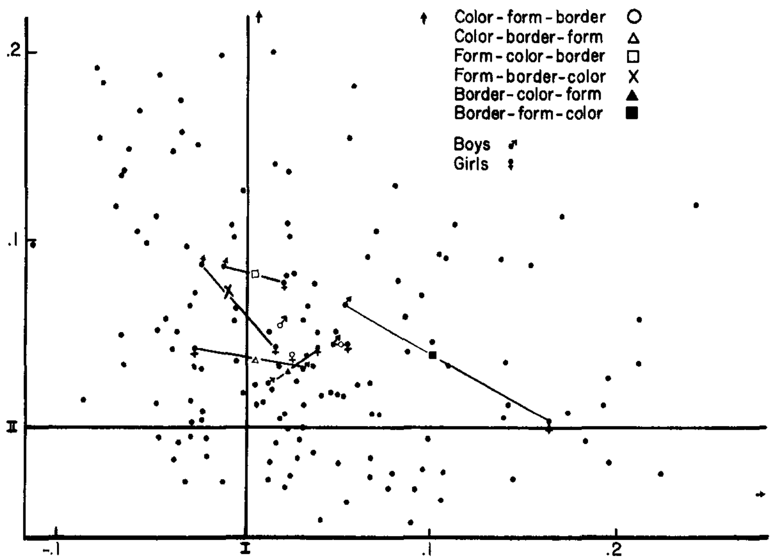

FIG. 2. Location of individuals in the individual differences space with means for each condition, each sex, and the Condition $\times$ Sex interaction.

bles (condition, grade, sex, or their interactions) the two dimensions of individual differences were entered as dependent variables in a multivariate analysis of variance (Jones, 1966). This analysis revealed significant differences in the centroids of the different conditions ($F = 6.35$, $df = 10/190$, $p < .001$). The centroid locations are given in Table 1. Univariate F tests indicated that Dimension II contributed more variance than Dimension I. Dimension II was highly significant ($F = 12.53$, $df = 5/96$, $p < .001$) while Dimension I was of borderline significance ($F = 2.07$, $df = 5/96$, $p = .075$) which was also indicated by the horizontal versus vertical dispersion of the means in Figure 2. The F ratios were not independent and thus could only indicate relative importance of the two dimensions. Once significant differences among the conditions had been found, a discriminant analysis was performed to determine what linear combination of the dimensions best discriminated among the conditions. This analysis revealed one significant discriminant function which gave Dimension II a weighting of 16.263, and Dimension I a weighting of 6.289, again indicating that the second dimension contributed more to the differences among the conditions.

The relative salience (cue preference) of the three cues for children appeared to be the major determiner of the condition effect. Children in conditions form-border-color and form-color-border, where the form cue was the most valid cue, had the highest loadings on Dimension I. The second highest loadings were for conditions color-form-border and color-border-form where color was the most valid cue and the lowest for conditions border-color-form and border-form-color where border was the most valid cue. The same ordering of the physical characteristics of the cues (form, color, border) was found when the condition loadings on Dimension II were examined. The conditions with the highest loadings on Dimension II were border-form-color and color-form-border where the form cue was of intermediate validity. The conditions in which color was of intermediate validity, border-color-form and form-color-border, had the second highest loadings on Dimension II. Again, the loadings of the conditions where border was of intermediate validity, color-border-form and form-border-color, were lowest on Dimension II as they had been on Dimension I in the two conditions in which border had the highest validity. Form also appeared to be the most used of the cues when it was the least valid. Conditions color-border-form and border-color-form had loadings closest to the origin of both Dimension I and Dimension II. The use of color and border when they were least valid did not show the

TABLE 1

MEANS FOR EACH SEX, EACH CONDITION, AND THE CONDITION × SEX INTERACTION ON THE TWO DIMENSIONS OF INDIVIDUAL DIFFERENCES

Condition	Dimension					
	Boys		Girls		Total group	
	I	II	I	II	I	II
Color-form-border	.044	.050	.044	.055	.043	.055
Color-border-form	.031	.032	.041	−.025	.038	.002
Form-color-border	.084	−.011	.076	.021	.081	.003
Form-border-color	.087	−.023	.042	.017	.067	−.006
Border-color-form	.023	.014	.041	.039	.031	.024
Border-form-color	.065	.054	.000	.164	.032	.109
Total conditions	.056	.019	.037	.025		

ordering they had shown on the two dimensions.

Also significant were the differences between the centroids for the sexes ($F = 3.61$, $df = 2/96$, $p < .05$; see Table 1). A discriminant analysis revealed that a linear combination of the dimensions which weighted Dimension I (9.758) and Dimension II (14.511) best discriminated among the sexes. Boys, in general, showed a slightly greater tendency to use the cue of highest validity than did girls. But girls showed a slight tendency to use the cue of intermediate validity more than boys.

And, finally, the interaction of Condition × Sex was significant ($F = 2.28$, $df = 10/190$, $p < .05$; see Table 1). Again the discriminant function weighted Dimension II (14.757) more than Dimension I (9.422). This interaction revealed a tendency for boys to use the cues of highest and intermediate validity no matter what their physical characteristics, while girls tended to use the form cue in combination with the most valid cue. When form was the most valid cue (form-color-border and form-border-color) boys relied on the form cue and the least valid cue, while girls in the form-color-border and form-border-color conditions tended to rely on the most valid and intermediate cues (more so in form-color-border than in form-border-color).

Analysis of Variance of Latencies

A 6 (Condition) × 4 (Grade) × 2 (Sex) × 8 (Blocks) analysis of variance on the latencies in seconds for each trial block yielded a significant main effect of grade ($F = 10.19$, $df = 3$, $p < .001$) which showed that latency increased with grade. Third graders averaged 1.67 seconds from onset of stimulus display to start of response, fifth graders, 1.85; seventh graders, 2.58; and ninth graders, 3.40. There was also a significant main effect of blocks, due largely to longer latencies in the first and fifth blocks.

The Condition × Blocks interaction was significant ($F = 1.49$, $df = 35/672$, $p < .05$) with the color-border-form condition showing the longest latencies, with latencies increasing over blocks. Border-color-form and color-form-border conditions started with fairly long latencies during Block 1, but dropped over trials, with the color-form-border condition falling more rapidly than condition border-color-form. Condition border-form-color also started with fairly long latencies, but they dropped rapidly over trials. Latencies in conditions form-color-border and form-border-color remained shortest throughout the trial blocks. All conditions showed a jump up in latencies during Block 5 for reasons that cannot be discerned.

Also significant was the Sex × Conditions × Blocks interaction ($F = 1.47$, $df = 35/672$, $p < .005$). Latencies for both sexes showed the same pattern in the form-color-border and form-border-color conditions although boys had longer latencies in the form-color-border condition, and girls had longer latencies in condition form-border-color. Girls had longer latencies in condition color-border-form and their pattern of latencies was different from that of boys. In all other conditions boys had longer latencies than girls, but showed varied patterns of latencies over blocks.

To discover if latencies were related to the cue weightings, the correlation between the latencies and the cue weightings for each cue were found and transformed to Z scores. A 6 (Condition) × 4 (Grade) × 2 (Sex) × 3 (Cue Weighting) × 8 (Blocks) analysis of variance of the Z scores yielded only a main effect of blocks ($F = 6.26$, $df = 7/672$, $p < .001$) which showed that latencies went from being negatively correlated with cue weight to being slightly positively correlated with cue weight over trial blocks.

The Grade × Blocks interaction was also significant ($F = 2.10$, $df = 21/672$, $p < .005$). For third graders latency was virtually uncorrelated with cues, varying from positively to negatively correlated from one trial block to the next. Fifth graders started out with latencies negatively correlated with cue weights in the first block of trials, but by the eighth block showed a positive correlation. Seventh graders tended toward an increasingly positve correlation over trials, and ninth graders performed much like third graders, but with less variability in their correlations over trial blocks.

Discussion

That children learned to use multiple cues simultaneously was evidenced by the significant increase in cue-utilization coefficients over trials. However, the children's performance was somewhat different from that of adults (Summers, 1962; Todd & Hammond, 1965; Uhl, 1963). While children did show a tendency to respond to the cues on the basis of their validities, as adults do, they appeared to be much more influenced by the salience of the physical characteristics of the cues.

The effects of the cue salience have also been reported in studies of children's discrimination learning (e.g., Smiley & Weir, 1966; Suchman & Trabasso, 1966) which have indicated that children learn faster when their preferred dimension (or cue) was relevant to solution. In the present study, cue salience (or children's cue preference) could either help or hinder the learning process, depending on the condition in which the child was placed. If a child's preferred cue was also the most valid cue it should aid his learning, if not it should act as a hindrance. This appeared to be the case.

The cues in the present study were color, form, and border. Children's preference for form over color after approximately 5 years of age has been fairly well documented (Brian & Goodenough, 1929; Calvin, Clancy, & Fuller, 1956; Seitz, 1968). (To the author's knowledge, preference for border has not been assessed.) It was not surprising, therefore, to find that form was the most salient cue for 8–13-year-olds in the present study.

The effects of cue salience on performance showed up in the multivariate anlaysis of variance of the individual differences space, where children's cue preferences (as reflected by cue use) appeared to be form > color > border, when comparing the use of all three cues when each was most valid. The same ordering held when the use of the cue of intermediate validity was examined. Univariate analysis of variance of children's cue-utilization coefficients revealed the same general phenomenon: Children's cue-utilization coefficients tended to be highest for the form cue, no matter what its validity.

The data for latency of responding was also related to the influence of the salience of the cues affecting children's performance. In the form-color-border and form-border-color conditions, where the apparently most salient cue, form, was also the most valid cue, children had the lowest latencies of responding, while in condition color-border-form, the only condition in which form did not have an overwhelming effect, the latencies were the highest. It is possible that when children find the cue they prefer is also the most valid, they respond quickly, relying primarily on the preferred cue, but when the preferred cue is not the most valid, they spend more time looking at all the cues, in an attempt to decide how to use them.

The analysis of individuals revealed two dimensions of individual differences which were interpreted to represent children's use of the cues. The first dimension related primarily to the use of the most valid cue, the second seemed to represent use of the other two cues. The implication of finding only two dimensions of individual difference is that children may only be able to effectively use two-stimulus dimensions (or cues) at a time. Summers (1962) reported that the ninth graders' cue-utilization coefficients approximately matched the ecological validities of the most valid and intermediately valid cues, but not the least valid cue (for the least valid cue, cue utilizations were lower than the ecological validity). Imai and Garner (1965) found that college students could classify stimuli on the basis of one or two dimensions without difficulty, but after two dimensions were reached, increasing the number of dimensions interfered with classification. And finally, Eimas (1965) found compounds to be more efficient than components in children's learning, but his compounds were of only two dimensions.

It may well be the case that for children multiple dimensions may mean just two dimensions. That is, children may be able to use the information in two dimensions of the stimuli, but when presented with a task like the present one and asked (or told) to use more than two, their ability to deal with the information becomes overworked, resulting in lowered performance overall. Certainly it is the case that the roles played by the type of stimuli, and the type of task in the processing of multidimensional information must be further explored.

From Piaget's theory of the development of logical thinking in children, it had been expected that there would be marked differences in the performance of third and fifth graders when compared with seventh and ninth graders. This did not turn out to be the case. Children's achievement correlations increased with increasing grade in school, the greatest increase coming between the fifth and seventh grades, but similar grade differences did not appear in the analysis of the cue-utilization coefficients or of the individual differences.

The children in this research did not reach the levels of achievement or cue utilization that have been reported for older subjects. The lower achievement scores and cue-utilization coefficients may have been due to the number of trials used in the research. Research with older subjects has used 200 or more trials at the task, while in the present study only 128 trials were used and the task was simplified in hopes that learning would occur without boring the children or keeping them from the classroom for too long a time period. However, the smaller number of trials may still have prevented children from learning to use the cues according to their validity, especially since it was necessary for many children to overcome the effects of cue salience before they could respond in accordance with the cue validities.

When the achievement scores and cue-utilization coefficients of the present research were compared with those found by Summers (1962) for the first 128 trials of his experiment, it appeared that children in the present study had reached approximately the same levels of achievement and cue utilization after 128 trials as had the subjects in the Summers study. Since Summers subjects were ninth graders it is reasonable to expect that given more trials than 128, older subjects in the present study would have been able to reach the higher levels of achievement and cue utilization which Summers found after 384 trials. If the younger children, given more trials, did not improve, it would lend support to Piaget's theory that logical thinking does not occur until 11 or 12 years of age.

Latencies of responding showed a significant increase over the four age groups, with the latencies of the ninth graders the longest. Forsman (1967) has shown that latencies lengthen with increasing task complexity. For older children the present task may be more complex because they try to follow the instructions to the letter and to use all three cues, while younger children may be content to rely on only one or two cues. Thus latencies for older children may be longer due to the more complex nature of the task for them.

Children's performance at the task also differed from that of adults in that sex differences were found in the children's performances. Todd and Hammond (1966) and Uhl (1963), using undergraduate students, analyzed for, but did not find, sex differences in performance at multiple-cue tasks. The present research found a distinct difference between the performances of boys and girls. The multivariate analysis of the individual differences space indicated that boys tended to use the most valid cue to a greater extent than did girls, when all conditions were included, and the univariate analysis indicated that the cue salience may have been more influential for girls than for boys. Neither Seitz (1968) nor other investigators have reported differences between the sexes on dimensional preference.

There are three hypotheses which need to be investigated as explanations for the sex differences found in this research. First, boys may be less rigid than girls (Cunningham, 1965; Luchins & Luchins, 1959) and therefore more able to break their preference set and use the information in the feedback to learn about the validity of the cues. Second, boys may be less anxious than girls (Sarason, Davidson, Lighthall, Waite, & Ruebush, 1960) and thus be more able to shift from the use of their dominant or preferred cue to the use of other cues (Casteneda & Lipsitt, 1959). And third, boys tended to have longer latencies in responding than girls which may be an indication of longer decision times, which in turn may have resulted in more learning about the varying cue validities.

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