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ABSTRACT

Two studies are reported in which the relative difficulty of the utilization of two response strategies, matching and oddity, was assessed. Subjects for the first study were children ages 5-7, 8-10, and 11-13 years; in the second study, college adults were tested. Generally, subjects took more trials to learn matching problems than oddity problems. For the younger Ss: (1) oddity problem solving improved with age; and (2) matching problem solving in girls, but not in boys, improved with age. In the adult Ss, no sex differences in respect to problem type were observed. A model of matching and oddity problem-solving is presented which proposes: (1) that problem-solving involves the utilization of appropriate response strategies; (2) that a hierarchy of response strategies develops and the dominance of the hierarchy remains fairly constant across ages once established; (3) consistent matchir responding involves suppression of the domanant oddity str... and (4) the mediation of inhibitory responses of more dominant ... nses takes time. The implications of the results for educational practices are discussed. (Author/TL)

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A Developmental Investigation of Oddity Concept Formation in Children

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SUMMARY

In a developmental investigation, the relative difficulty of the utilization of two response strategies, matching and oddity, was assessed in children 5-7, 8-10, and 11-13 years of age. Half of the subjects in each group were required to solve a series of oddity problems in which responding to the odd stimulus, a stimulus which was different with respect to some attribute, in a three-stimulus array was associated with reward. The other subjects in each age group were required to respond to either of two stimuli which were alike with regard to some attribute in the three-stimulus display. Generally, subjects took significantly more trials to learn matching problems than oddity problems. However, it was found that for both boys and girls, oddity problem-solving improved with age, that matching problem-solving in girls improved with age, and that matching problem-solving did not improve with age in boys. A model of matching and oddity problem-solving was presented, and it was proposed that the sex difference observed in regards to matching responding might be attributable to a fluctuation in the boys' persistence in the utilization of internal cues to inhibit the dominant oddity response.

In a second study, the relative difficulty of matching and oddity problem was tested in college adults. Again, matching was more difficult than oddity problem-solving, but no sex differences in respect to problem type were observed. The results of the second study lent further support for a model that proposed that: (1) problem-solving involves not only the utilization of symbolic representational responses or concepts but also the utilization of appropriate response strategies; (2) a hierarchy of response strategies develops and the dominance of the hierarchy remains fairly constant across ages once established; (3) consistent matching responding involves the suppression of the dominant oddity strategy; and (4) the mediation of inhibitory responses of more dominant responses takes time. The implications of the results for educational practices were also discussed.

EXPERIMENT I

Solution of the oddity problem requires that the subject make an approach response to a stimulus that is "different", with respect to some kind of cue, from the other stimuli in a stimulus array. The oddity problem can be viewed as a complex discrimination task requiring a relational solution (House, 1964). The task is more "complex" than simple discrimination learning in that any stimulus may be correct on some trials and incorrect on others. Specific habits to specific cues are ineffectual for solution since the correct choice is determined by a relation, that of difference, between the odd stimulus and the others in the set (House, 1964). Harlow (1951) has proposed that the matching and oddity problem are compliments of each other since in the matching problem the subject is rewarded for an approach response to one of the two stimuli that are "alike" or "the same" with respect to some cue. Similarity and oddity can be taught with the same set of stimuli and in neither problem is the critical cue a specific stimulus, a particular color or form, nor is it a single stimulus, a particular circle or red, but rather a relationship among several stimuli (Scott, 1964). As Lubker and Spiker (1966) have pointed out:

> ...the theoretical significance of the study of the oddity problem lies in the fact that current non-mediational stimulus-response theories of discrimination learning do not provide any ready analysis of such situations. The main difficulty that such theories have is in specifying the stimulus aspects that con[illegible] choice behavior (p. 24).

Thus, it would appear that the study of oddity and matching problem-solving would provide useful information about concept formation and concept utilization and a suitable testing ground for competing mediational theories of learning (Kendler and Kendler, 1968; House and Zeaman, 1963; Tighe and Tighe, 1968; Mackintosh, 1965; Lovejoy, 1968; Fellows, 1968). Despite the possible relevancy of these tasks for a theory of cognitive functioning, systematic investigations of human performance on oddity and matching tasks have just recently begun to appear in the literature.

The most frequently investigated variables that have been related to oddity problem-solving in humans are chronological and mental age (Ellis and Sloan, 1959; Martin and Blum, 1960, 1961; Lipsitt and Serunian, 1963; Gollin and Shirk, 1966). These data indicate that the probability that the subject will learn the oddity task increases as a function of age and that there is a discontinuity in this function at about six years, i.e., there is little evidence of solution by children under five or six years of age.

Gollin, Saravo, and Salten (1967) observed the facilitating effects upon oddity learning of increasing the number of identical stimuli in the array; however, the potency of this variable was dependent upon the child's developmental level. Lubker and Spiker (1966) demonstrated the adverse affect upon oddity performance of increasing the number of irrelevant dimensions in dimension-abstracted oddity problems given to third-and fourth-grade children. House (1964) attempted to facilitate oddity learning in retarded children with a variety of pretraining methods and discriminandum. As House pointed out, the results of the study were difficult to interpret because of methological considerations; notwithstanding the fact that, because of the procedures employed, the question arose as to whether the subjects learned an oddity concept at all. Unfortunately, much of the available data on oddity learning shares this same methodological problem. The task may be so constructed that the subject need not learn the oddity concept in order to receive reinforcement most of the time, i.e., the subject may attain learning criterion by the solution of a series of conditional discriminations or successful use of a stimulus or position alternation strategy. This methodological dilemma is likely to arise when: (1) no transfer tests with different stimuli are given to determine oddity responding; (2) training is multi-trial, i.e., the same stimulus array occurs on successive trials until the subject chooses the odd stimulus for a number of consecutive trials; (3) a very limited number of stimulus arrays and combinations are employed, and (4) the odd stimulus appears in only two of the three (or more) response positions (two-position oddity). Although such procedures have been employed extensively in studies of oddity learning in infrahuman subjects (Schrier, Harlow, and Stollnitz, 1965), they would not appear to be optimal conditions for assessing oddity concept formation wherein any particular stimulus, regardless of its specific attributes and properties, may be the correct stimulus and correct choice is determined by a relationship (House, 1964).

Lashley (1938a) attempted to establish matching behavior in two rats using a jumping stand apparatus with three doors. The "sample" stimulus (one of the two stimuli which were alike) always appeared on the center door which was always locked; and the two choice stimuli appeared on the two side doors. The door displaying the matching stimulus was open and led to food; the door displaying the non-matching stimulus was locked. The stimulus used as the sample and the position of the matching stimulus varied between trials. Although it should be noted that only 200 trials of differential reinforcement were given, matching behavior in these subjects was not established. Lashley proposed that the difficulty was due to the rat's inability to respond conditionally. However, in a subsequent study, Lashley (1938b) demonstrated that rats could be trained to choose an erect or an inverted triangle according to whether the background was black or striped which indicated that the rat's failure to acquire matching responding was not due to their inability to respond conditionally. Lashley concluded that the difficulty of the matching task arose because in matching, the sample and the choice are not only spatially separated but also of "different significance", i.e., while the choices are stimuli to be "jumped at", the sample is to be "looked at" only. Since the sample is not responded to, it is not oriented toward, and thus not "received" by the rat.

Ferster (1960) used a procedure to insure that an initial orienting response to the sample was a part to the whole chain of the matching behavior in pigeons. He trained the subjects to peck an illuminated center key which lighted up two side keys and extinguished the center one. Reinforcement was contingent upon a response to the key of the same color as the center key (two-position matching), and the color of the sample and the position of the matching stimulus varied from trial to trial.

In the present study, it is proposed that the subject's facility in the oddity and matching tasks is dependent upon at least two cognitive operations. The first is the utilization of appropriate symbolic representational responses which characterize the relational value between the stimuli since reliance upon the association with reward of any particular cue of any stimulus compound will not result in consistently correct responding. As in the case of oddity, "red-cirle" may be the correct stimulus on trial n when it appears with two "blue-circles", but the incorrect choice on trial n+1 when it appears with one "blue-circle" and one "red-circle" --- and conversely in the case of matching. The second operation is the utilization of the appropriate problem-solving response strategy. In the case of the oddity problem the appropriate response strategy is one of responding to "difference"; in matching, responding to "sameness". This conceptualization of the matching and oddity problem-solving situation is most similar to Kendler and Kendler's (1970a) coordinated single-unit mediational S-R theory which proposes that there are at least two levels of representation entailed in reversal shift behavior. One level consists of symbolic responses to each stimulus value. Another involves the utilization of learning strategies, rules which operate at a representational level (Kendler and Kendler, 1970b). The question of the role that the oddity and matching response strategies play in the problem-solving behavior of children was the focus of the present study. If the utilization of symbolic representational responses is a sufficient condition in oddity and matching solution, then there should be no difference in the relative difficulty of the two problems given the same stimulus conditions in both problems. However, if different response strategies are required by the two kinds of problems, then differences in the relative ease with which the two kinds of problems are solved might be expected and such differences would reflect differences in the relative ease of response strategy utilization.

Fellows (1965) made an analysis of theresponse strategies exhibited by 4- and 5-year olds in a two-choice matching to sample task and found that unless the transition from easy to difficult discrimination problems was made gradually, the established matching habit would break down and was usually replaced by oddity responding. Based on these and other data, Fellows (1968) concluded that there is a hierarchy of hypotheses of response strategies that are likely to be employed by the child, ranging from simple position perseveration or alternation responding, to the outcome hypotheses (win-stay, lose-shift), to oddity responding, and finally to matching.

The purpose of the present study was to investigate possible developmental differences in the utilization of oddity and matching response strategies. Developmental differences have been found in relation to the utilization of the win-stay, lose-shift strategies (Levinson and Reese, 1967). The present study also attempted to employ such procedures as to avoid the methodological problems of previous studies, mentioned above, investigating the relation between age and oddity problem-solving.

Method

Subjects. Subjects were 144 children from the DeKalb Public Schools, DeKalb, Illinois. Forty subjects, 20 male and 20 female, were 5-7 years of age (range = 5-0 to 7-11, mean = 7-0); 40, 20 male and 20 female, were 8-10 years of age (range = 8-0 to 10-10, mean = 9-3); and 64, 32 males and 32 females, were 11-13 years of age (range = 11-4 to 13-3, mean = 12-0). Mean IQ scores for the three age groups were 107.04, 111.82, and 101.14, respectively; IQ scores were taken from the subjects' school records and were obtained from a variety of tests under a variety of testing conditions across subjects and thus represent indicative rather than definitive measures. A distribution of the socioeconomic status of the subjects' families is presented in Appendix A. The socieconomic status was determined by the U.S. census tract of 1960, according to the occupation of the subject's father; if the father was not living, the mother's occupation was used as an index.

Apparatus. A Totally Automated Psychological Assessment Console (TAPAC), designed and developed by Lehigh Valley Electronics, was employed. The TAPAC presented materials to the subject in audio and visual form from a console display.

The front panel of the console consisted of an 8 1/2" X 11" center screen with nine rear-screen projector response keys located just below. All but three, centrally located, response keys were covered by a strip of cardboard for purposes of the experiment. An "advance" and "ready" button were located on the lower left and lower right hand sides, respectively. An "incorrect" lamp, a "correct" lamp, and a 4" speaker were located above the screen. All of the response devices and the viewing screen were mounted on a slanted surface to facilitate easy viewing and responding.

The visual display mechanism, housed within the console, consisted of an 8 1/2" X 11" rear projection screen upon which visual material was presented. The visual material, obtained from 35mm transparencies mounted on aperture cards, was focused and directed to the polacoat rear screen projection surface.

Through the card handling system, a stack of aperture cards was stored and fed one-at-a-time into the projector. When the card was moved into position, the information punched in the card was read into memory. The information was held in memory until the next card moved into the projector.

The audio presentation system, housed in the rear of the console, consisted of a specifically modified tape recording device which was capable of presenting audio information and concurrently supplying control signals to the visual presentation system so that both the audio and visual presentations were in proper synchronization. The audio messages were presented to the subject by means of the speaker in the front panel, and the volume was controlled at a comfortable, but distinctive level.

Programming for the TAPAC consisted almost entirely of solid state logic elements mounted on cards in a roll-out drawer above the card reader. It performed all of the necessary coding, decoding, and timing of all the information required for each presentation. It included all the necessary drivers for starting and stopping the card handler, card reader, tape recorder, and devices to record the subject's responses.

Data was recorded on a 9-channel printer located in the back of the console. A print occurred for every response on each of the following measures: response latency (recording from the time that the subject turned the stimuli on by pressing the "ready" button until subject responded to one of the response buttons), card number, correct/incorrect response, response key pressed, and total correct responses. Recording of latencies was in 1/10 seconds.

The aperture cards used consisted of two basic elements: the 35mm transparency of the visual stimulus material, and the punched data section containing information pertaining to the visual material. The visual testing material consisted of a series of slides showing three pictures, one centered directly above each of the three response buttons which lighted up on each trial.

When a correct response was made, the "correct" lamp came on and a "bell" tone sounded; when an incorrect response was made, the "incorrect" lamp lighted and a buzzer sounded.

Procedure. The experimental design was a 3(age) X 2(problem) X 2(sex) X 2(dimension) randomized block design. Within each of the three age groups, subjects were randomly assigned to one of four problem conditions, with the restriction that there was an equal number of males and females within each condition: matching-color, matching-form, oddity-color, and oddity-form. In the matching problem condition, the subject was reinforced for responding to either one of the two stimuli which were alike in the three-stimulus display. Thus, if two blue circles and one red circle were displayed, a representative trial in a series of matching-color problems, response to either of the blue circles was reinforced, but response to the red circle was not. Under the oddity problem condition, the subject was reinforced for responding to the odd stimulus, the stimulus which differed from the other two. Thus, if two red triangles and one red circle were displayed, a representative trial in a series of oddity-form problems, response to the red circle was reinforced. Since all subjects solving color problems received the same schedule of stimulus presentations and all subjects solving form problems received the same schedule of stimulus presentations, only the response contingency, matching or oddity, differed across subjects within each of the dimension conditions.

Each subject learned either the matching or oddity problems with the appropriate set of training stimuli which consisted of a set of 27 unique trials, i.e., the training set constituted single-trial matching or oddity since no particular three-stimuli combination occurred on any two consecutive trials. Further, position of stimulus appeared equally often in the "right", middle", and "left" position (3-position matching or oddity). If the subject had not reached the learning criterion of 10 consecutive correct responses within the first 27 trials, the program reset to the beginning of the schedule and continued in this fashion until criterion was reached on the training set.

As soon as the subject attained criterion on the training set, the card reader automatically began to reject cards which served as a cue for the experimenter to insert a new deck of cards which presented to the subject two transfer tests. The first transfer task tested for generalization of the acquired response strategy, either matching or oddity, to new stimuli of the same dimension that the subject had used in the training set, an intra-dimensional (ID) test. Thus, if the subject had learned either matching-color or oddity-color problems, in the ID test, matching or oddity solution was again based on color cues but the set of problems contained color combinations that he had not seen in the training set. The second transfer task tested for generalization of the acquired response strategy to a new dimension, an extra-dimensional (ED) test, and matching or oddity solution was based on form cues if the subject had learned either matching-color or oddity-color, or on color cues if the subject had learned either matching-form or oddity-form problems in the training set.

The stimuli consisted of four sets of problems. Set 1 constituted the training stimuli for matching-form and oddity-form problems and consisted of three basic problems: (a) two squares and one triangle, (b) two circles and one square, and (c) two triangles and one circle. Each kind of problem occurred in three different colors (red, blue, and green); and since the position of each stimulus per problem was presented in three different position orders ("right", "middle", and "left"), Set 1 yielded 27 training trials without repetition of any single problem in the same color with stimuli in the same position of presentation.

Set 2 constituted the training problems for oddity-color and matching-color and consisted of three basic problems: (a) two greens and one blue, (b) two blues and one green, and (c) two reds and one blue. As with Set 1, these problems varied as to the forms employed (squares, circles, and triangles) and to the position of stimuli yielding 27 training trials.

Set 3 constituted the transfer test problems for oddity-form and matching-form problems and consisted of three new problems: (a) two squares and one circle, (b) two circles and one triangle, and (c) two triangles and one square. Each problem was presented in each possible color, and the position of stimulus was randomized yielding 9 transfer test trials.

Stimulus Set 4 constituted the transfer test problems for oddity-color and matching-color problems and consisted of: (a) two greens and one blue, (b) two blues and one red, and (c) two reds and one green. Each problem appeared in each possible form, the position of stimuli being randomized, yielding 9 transfer test trials.

The subjects were tested in a mobile unit which was situated near the school building. Participation in the experiment was voluntary. The subject was brought to the mobile unit and seated at the console of the TAPAC and instructed, in language appropriate to his age, that he was going to play a game and that he could win a prize, some gum or candy from the candy "store". The experimenter then questioned the subject to obtain such information as the subject's age, birthdate, father's occupation, mother's occupation, etc. Then the subject was told that the machine would tell him what to do and when to do it, at which point the experimenter turned on the audio-visual systems which gave the subject instructions as to how to work the machine. A transcript of the recorded instructions is presented in Appendix B. The older subjects (11-13 year-olds) were also informed that the problems had actually been designed for younger children and they should not try to complicate the task but "take it for what it is". At the conclusion of the instructions, the experimenter asked the subject if he had any questions. If the subject had none, the subject initiated the testing by pressing the ready button. If the subject had not understood the instructions, the experimenter explained that three pictures would come on the screen when he pressed the ready button, that the subject should look at <u>all</u> the pictures before he chose, that the object of the game was to choose a correct picture <u>every</u> time, and that when he had learned to do that, he could choose a prize from the candy "store". Subject was also reminded that the "bell" meant that he had chosen a correct picture and that the buzzer meant that he had chosen an incorrect picture. These instructions were repeated to the subject after trials 54, 108, 162, 216, and 270 had he not met the learning criterion on the training set. No subject was dropped due to a failure to learn.

It is important to note that the two practice problems in the recorded instructions gave <u>every</u> subject an example of both a matching strategy and an oddity strategy. On the first practice problem, the screen displayed three red rectangles with the letter "A" in the left, the letter "B" in the middle, and the letter "C" in the right rectangle. Subject was shown to press the button under the left picture, then the button under the middle picture, and finally the button under the right picture. The buzzer sounded following responses to the left and middle buttons, while the bell sounded after response to the right button (two incorrects and one correct, or oddity). On the second practice frame the same pictures were presented and the subject was asked to press the buttons again in the same order. This time, however, the bell sounded following responses to the left and middle buttons and the buzzer sounded after response to the right button (two corrects and one incorrect, or matching).

After the subject had attained learning criterion on the training set and had received both the ID and ED transfer problems, a post-test interview was conducted to determine if the subject would verbalize about the problem-solving strategy that he used and about the concepts and instances of concepts he employed or noted.

The response measures examined were: trials to criterion, errors to criterion, ID test errors, ED test errors, and mean response latencies for the first-, third-, and fifth-fifth's of the subject's trials to criterion.

Results

Trials to criteria. In accordance with Winer (1962, p. 220), scores on the trials to criterion measure were submitted to square root transformation. All means presented are derived from transformed scores. A 3(age) X 2(problem) X 2(sex) X 2(dimension) analysis of variance yielded a significant main effect for age ($F = 4.12$, $df = 2/120$, $p < .05$). Mean trials to criterion were 6.82, 5.61, and 5.22 for the 5-7, 8-10, and 11-13 year-olds, respectively. A main effect was also found for problem ($F = 8.11$, $df = 1/120$, $p < .01$); subjects took significantly more trials to learn matching problems ($\bar{X} = 6.35$) than oddity problems ($\bar{X} = 5.06$).

TABLE 1

Mean Trials to Criterion According to Age, Problem, and Sex

	Matching		Oddity	
	Males	Females	Males	Females
5-7 year-olds	6.20	7.94	6.98	6.18
8-10 year-olds	6.74	6.22	4.63	4.88
11-13 year-olds	7.37	4.90	3.75	4.87

However, the interaction for age, problem, and sex was significant ($F = 3.52$, $df = 2/120$, $p < .05$). As indicated in Table 1, both the boys' and the girls' oddity performance improved with age, and the girls' matching performance improved with age. The boys' matching performance did not improve with age. Separate trend analyses for linearity of the boys' matching and the girls' matching performance indicated no significant linear comp nt for different-aged boys ($F = 0.61$, $df = 2/33$, $p > .05$) while the linear component for the different-aged girls' performance was significant ($F = 6.49$, $df = 2/33$, $p < .05$).

Further, a significant interaction for age, sex, and dimension was obtained ($F = 3.40$, $df = 2/120$, $p < .05$). Inspection of Table 2 indicates that this interaction was primarily due to the poor performance of the 5-7 year-old girls on form problems, the improvement in trials to criterion with increasing age, and the more dramatic improvement in girls on form problems.

TABLE 2

Mean Trials to Criterion According to Age, Sex, and Dimension

	Males		Females	
	Color	Form	Color	Form
5-7 year-olds	6.85	6.32	5.16	8.95
8-10 year-olds	4.94	6.43	5.59	5.52
11-13 year-olds	5.54	5.58	4.76	5.02

A further breakdown of the interaction showed that while there was an improvement with age in girls on both form and color matching problems (the improvement was more dramatic on form problems because of the poor performance of the 5-7 year-old girls), there was no improvement with age by boys on either form or color matching problems (Table 3).

Errors to criteria. A 3(age) X 2(problem) X 2(sex) X 2 (dimension) analysis of variance was performed on subjects' errors to criterion. A significant main effect for age was obtained ($F = 3.86$, $df = 2/120$, $p < .05$); mean errors were 23.60, 14.12, and 10.81 for the 5-7, 8-10, and 11-13 year-olds, respectively. No other main effect or interactions were found.

ID test errors. ID test errors were submitted to arc sine transformation as recommended by Winer (1962, p. 221). A 3(age) X 2(problem) X 2(sex) X 2(dimension) analysis of variance demonstrated no significant main effects and no significant interaction.

TABLE 3

Mean Trials to Criterion for Matching Problems According to Age, Sex, and Dimension

	Males		Females	
	Color	Form	Color	Form
5-7 year-olds	7.12	5.25	5.62	10.24
8-10 year-olds	5.65	7.82	6.97	5.45
11-13 year-olds	7.42	7.32	4.59	5.22

ED test errors. ED test errors were also submitted to arc sine transformation and the 3 X 2 X 2 X 2 analysis was performed; only transformed means are reported. A significant main effect for age was found ($F = 3.72$, $df = 2/120$, $p < .05$); the mean ED errors were 7.71, 1.93, and 7.03 for the 5-7, 8-10, and 11-13 year-olds, respectively. The main effect for problem was significant ($F = 6.19$, $df = 1/120$, $p < .05$); the mean ED errors were 8.79, and 2.82 for matching and oddity problems, respectively.

TABLE 4

Mean ED Test Errors According to Age and Problem

	Matching	Oddity
5-7 year-olds	6.67	8.75
8-10 year-olds	3.87	0.00
11-13 year-olds	13.19	0.87

However, the interaction between age and problem was also significant ($F = 4.89$, $df = 2/120$, $p < .01$); while the occurrence of ED test errors for oddity problems decreased with age, the occurrence of errors for matching problems increased with age (Table 4).

Latency I. The first latency measure was obtained by calculating the mean latency of the first-fifth of trials of the subject's total number of trials to criterion. A 3 X 2 X 2 X 2 analysis of variance on the subjects' mean latencies demonstrated no significant main effects. However, a significant age X sex X dimension interaction was found ($F = 3.15$, $df = 2/120$, $p < .05$), and the mean latencies for this interaction are given in Table 5.

TABLE 5

Mean Latencies I According to Age, Sex, and Dimension

	Males		Females	
	Color	Form	Color	Form
5-7 year-olds	3.59	2.51	3.56	2.57
8-10 year-olds	2.85	3.71	4.04	2.66
11-13 year-olds	2.71	2.66	2.46	4.03

In the 5-7 year-olds, both boys and girls showed longer response latencies on color as compared to form problems. In the 8-10 year-olds, boys' latencies were longer for form than for color problems while the girls' latencies were longer for color than for form problems. In the 11-13 year-olds, although the boys' latencies were approximately equal for color and form problems, the girls' latencies were longer for form problems.

Latency II. The second latency measure was obtained by calculating the mean latency of the third-fifth of trials of the subject's trials to criterion. A 3 X 2 X 2 X 2 analysis of variance demonstrated no significant main effects and no significant interactions.

Latency III. The third latency measure was obtained by calculating the mean latency of the fifth-fifth of trials of the subject's trials to criterion which always included trials contained in the criterion run. A 3 X 2 X 2 X 2 analysis of variance showed no significant main effects and no significant interactions. However, one main effect and two interactions approached significance and appeared worthy of note particularly in light of the results demonstrated for the trials to criterion measure. Subjects' mean latencies on matching problems (2.44) was longer than the mean latencies for oddity problems (1.88) ($F = 3.42$, $df = 1/120$, $p < .10$). The interaction between age, sex, and problem also approached significance ($F = 3.04$, $df = 2/120$, $p < .10$). For both boys and girls (Table 6), response latencies decreased with age for oddity problems. Girls' latencies also decreased with age for matching problems, while boys' response latencies for matching increased with age.

TABLE 6

Mean Latencies III According to Age, Sex, and Problem

	Matching		Oddity	
	Male	Female	Male	Female
5-7 year-olds	2.33	3.03	2.77	2.00
8-10 year-olds	2.20	1.77	1.47	2.06
11-13 year-olds	3.38	1.79	1.69	1.59

Further, the age X sex X dimension interaction also approached significance ($F = 3.04$, $df = 2/120$, $p < .10$). An examination of Table 7 demonstrates that: (1) the response latencies of girls for color problems remained fairly stable with age;

TABLE 7

Mean Latencies III According to Age, Sex, and Dimension

	Color		Form	
	Male	Female	Male	Female
5-7 year-olds	2.99	1.94	2.11	3.09
8-10 year-olds	1.65	2.16	2.02	1.67
11-13 year-olds	2.17	1.61	2.90	1.77

(2) 5-7 year-old girls' latencies were longer for form than for color problems but form latencies decreased with age; (3) the

response latencies of the 5-7 year-old boys was longer for color than for form but latencies for color problems decreased with age; and (4) 11-13 year-old boys' latencies for form problems were longer than for color problems.

Discussion

The present data lend support to the model that solution and effective transfer in matching and oddity problem-solving involves not only the utilization of appropriate symbolic representational responses, such as "form" and "color" which help to characterize the relational properties of the stimuli, but also the utilization of appropriate response strategies. Since the appropriate concepts were the same for color-matching and color-oddity and for form-matching and form-oddity, the relative difficulty of the matching problems compared to the oddity problems demonstrated presumably lay in the difficulty of the utilization of the appropriate response strategy.

In a model of discrimination learning, Fellows (1968) has proposed that a hierarchy of hypotheses, response strategy hypotheses, exists. They are, in order of decreasing dominance or unavailability, simple position perseveration or alternation, outcome hypotheses (win-stay, lose-shift), oddity, and matching. Further, Fellows proposed that "oddity is, cognitively speaking, a simpler method" of responding and that persistent matching behavior requires the suppression or inhibition of the simpler mode of oddity. Thus, the matching behavior of a child solving simple matching problems would be "disrupted" and oddity responding reinstated if the subject were suddenly transferred to a more difficult matching problem or even to another simple discrimination if there were changing cues which might "distract" him.

In view of the evidence gained from developmental investigations of response inhibition and inhibition of associative responding (White, 1965; Kendler, 1970), it would be predicted from Fellows's model that oddity problem-solving would be relatively efficient for children of all ages, given that even the youngest child had both the oddity and matching hypotheses available to him and Fellows's data indicates that this is the case for the 5-6 year-old, and that the efficiency of matching behavior would increase with age. Matching problem-solving would improve with age because the older child would be more proficient at inhibiting simpler and/or more associative responses, at least provided there was no time limit placed on his response, i.e., he had the time to make the more "complex", "mediated" inhibitory response (White, 1965; Kendler, 1970).

This model, derived from Fellows's analysis, implies two propositions: (1) that the oddity strategy remains a more dominant strategy than matching with development; and (2) that the oddity relationship in the stimulus configuration, the stimulus that is different as opposed to the two that are alike, is the more salient relationship throughout development - it does not decrease or increase in salience with age. The results of the present study will be discussed in relation to these two propositions.

Contrary to the model presented above, oddity problem-solving did improve with age. One possibility is that the oddity relationship becomes more salient with age. An analysis was made of the percentage of subjects in each age group, regardless of problem type, who chose the odd stimulus on the first trial of training as a possible indicator of cue salience of the odd stimulus. The percentage of subjects chosing the odd stimulus on the first trial was 56.41 55.00 and 54.45 for the 5-7, 8-10, and 11-13 year-olds, respectively. Response choices on the first trial may have been determined by a number of factors - how well the child understood the instructions, etc. - and this measure may or may not have been a fair indicator of the cue salience. Nevertheless, if one were to accept response choices on the first trial as an indicator of cue salience, it would have to be concluded that the improved performance for oddity problem-solving cannot be attributed to changes in the salience of the odd stimulus but rather that with increasing age the oddity strategy becomes a more accessible strategy, it gains strength such that for the older child the oddity strategy is just as accessible as the outcome strategies.

The second proposition of the model concerns the relative difficulty of matching and oddity across age groups and whether or not efficiency in matching behavior improves with age. The matching performance of the girls did improve with age. However, the matching performance of the boys did not. Since the matching behavior of the girls was consistent with the expectations of Fellows's model and with the observed developmental trends in the efficiency of inhibitory behaviors, the performance of the boys was strikingly incongruous. A more explicity statement of the mechanisms involved in persistent matching behavior seemed required. Either there is a faster development of the availability of the matching hypothesis in girls and it becomes a stronger alternative more rapidly for girls, or the girls are demonstrating greater proficiency and efficiency with age in inhibiting the dominant oddity response. Several aspects of the data lend support to the latter interpretation. It is proposed that, within the age ranges studied, the appropriate strategies were equally available to both boys and girls but that the girls, particularly with increasing age, were more efficient in the persistent inhibition of the competing, dominant response to oddity.

One line of evidence for this interpretation comes from an examination of response latencies. Although there was no evidence for differential response latency patterns for boys and girls for the two types of problems early in the training trials, the trends of the response latencies in the latter phase of learning, Latency III, demonstrated the age X sex X problem interaction reflected in the trials to criteria measure. That is, for both boys and girls, response latencies decreased for oddity responding. However, while the boys' response latencies for matching responding tended to increase with age, the girls' latencies for matching tended to decrease - suggesting increased proficiency in inhibitory behavior on the part of the girls. A very effective internal cue for inhibiting oddity responding would be verbal rehearsal: "don't choose the odd one". It seemed possible that while both boys and girls might be equally likely to produce such an internal cue, particularly with increasing age, it might be that the girls tended to persist in the rehearsal of such a cue and became more proficient at this with age and with practice across trials. For the boys, even if they were more likely with increasing age to produce such internal cues, it appeared that the internal rehearsal did not persist over a sufficient number of trials to maintain matching behavior. It occurred to the author that if girls tended to persist in their internal rehearsal of the inhibitory cues while this rehearsal tended to fluctuate in the boys, then the response patterns on matching problems should be different for boys and girls. Implied is that there would be no significant difference between the boys and girls in terms of the total number of errors made on matching problems, but that the distribution of these errors should be different for the boys and girls. Once the girls had selected the matching strategy, if they persisted in the use of the strong, verbal internal cue, no further errors should occur. If the boys tended to fluctuate in the rehearsal of the internal, inhibitory cues, then their response patterns would be characterized by strings, and perhaps long strings, of correct responses interspersed with errors. An example of the two kinds of response patterns is presented (see next page) where "+" indicates a correct matching response and "-" indicates an incorrect or oddity response.

As a measure to be analyzed which might give an indication of the two kinds of response patterns, the largest number of correct responses between any two errors made was calculated for

Response Patterns

Pattern 1				Pattern 2				
-	+	+		-	+	+	+	+
-	+	+		-	-	+	+	+
-	+	+		+	+	-	+	+
+	+	+		+	+	+	+	
-	+	+		+	+	+	+	

each subject who made at least two errors. This measure was submitted to analysis in a 3(age) X 2(sex) X 2(dimension) analysis of variance; no significant main effects or interactions were found. However, the largest F ratio was obtained for the main effect for sex ($F = 1.73$, $df = 1/47$, $p < .25$) and the trend was in the predicted direction - boys tended to make more correct responses between any two errors than girls. Further, the analysis on errors to criteria had demonstrated no sex differences. Thus, the interpretation that the difference in matching performance between the boys and girls demonstrated a performance factor - girls tended to persist in the rehearsal of a strong internal cue for inhibitory behavior and efficiency in doing so increased with age, while the boys tended to fluctuate in this behavior - appeared tenable. It is certainly a testable hypothesis. If conditions are arranged such that fast instrumental responding is prohibited and overt verbal rehearsal is encouraged, the prediction based on the hypothesis presented above would be that the sex differences observed would be eliminated.

Finally, it might have been expected that the girls would have shown significantly fewer ID and ED test errors in matching behavior than the boys, while, in fact, both boys and girls made significantly more ED test errors on matching as compared to oddity problems. Further, whereas the frequency of ED test errors for oddity declined with age, ED test errors for matching tended to increase with age. However, it has been consistently demonstrated that ED shifts are difficult, particularly for older children (Kendler and Kendler, 1970a) which would simply suggest that the shift to another dimension for solution was a very powerful disruptive factor, even for the girls who had previously demonstrated persistent matching behavior.

EXPERIMENT II

The purpose of the second study was to assess the relative difficulty of matching and oddity problem-solving for adult college students. It was recognized that college students do not constitute a representative sample of the adult population; nevertheless it was of interest to see if the performance of college students could be predicted on the basis of the children's performance.

Method

Subjects. Subjects were 48 undergraduates enrolled in introductory psychology classes at Fordham University. Subjects, 24 males and 24 females, ranged in age from 17 years-9 months to 21 years-11 months, with a mean age of 19 years-3 months. A distribution of the occupational status of the subjects' families is presented in Appendix A and was determined as in Experiment I.

Apparatus. The same apparatus and stimulus materials used in Experiment I were employed.

Procedure. A randomized block design with three nesting variables, a 2(problem) X 2(sex) X 2(dimension) design, was used. Subjects were randomly assigned to one of the four problem conditions - matching-color, matching-form, oddity-color, and oddity-form - with the restriction that there was an equal number of males anf females within each condition.

As in Experiment I, subjects learned to criterion (10 consecutive correct responses) either matching or oddity problems with the appropriate training stimuli and then received both the ID and ED transfer tests. However, if the subject made more than two errors in either the ID or ED test series, problems from the training set were again given until the subject again made 10 correct responses at which time the subject received the ID and ED tests again. Such re-learning continued until the subject met two criteria for learning: having made 10 consecutive correct responses on the training set and having made no more than two errors on either the ID or ED test series.

Subjects were tested in an experimental room in the psychology building and procedures for testing were essentially those employed in Experiment I. However, subjects were told that the problems had originally been designed for younger children and they should try not to complicate the task. The recorded instructions used are given in Appendix C. The pretesting and post-testing interviews described in Experiment I were also given. In addition, at the conclusion of the posttesting interview, subjects were informed about the nature of the experiment, about the results of Experiment I, and about any questions they had concerning the experiment.

Results

Separate 2(problem) X 2(sex) X 2(dimension) analyses of variance were performed on each of seven response measures: trials to criteria, errors to criteria, ID test errors, ED test errors, Latency I, Latency II, and Latency III (latency measures being defined as in Experiment I). No significant interactions were found in any analysis.

Subjects took significantly more trials to criterion for matching ($\overline{X}$ = 31.17) than for oddity problems ($\overline{X}$ = 10.46) (F = 10.61, df = 1/40, $p < .01$). It was possible that the difference between the two types of problems was inflated because four subjects did require re-learning trials and all four solved matching problems. Thus, the trials to criterion measure was recalculated excluding re-learning trials and taking only the number of trials to 10 consecutive correct responses as the learning criterion. Scores were submitted to a square root transformation, and means reported are derived from transformed scores. As in the previous analysis, subjects' mean trials to criterion for matching problems (4.36) was significantly larger than the mean for oddity (3.22) (t = 3.25, df = 46, $p < .01$).

Subjects also made more errors to criterion on matching ($\overline{X}$ = 8.33) than on oddity problems ($\overline{X}$ = 0.33) (F = 10.31, df = 1/40, $p < .01$). A re-calculation of errors to criterion was obtained by excluding errors on re-learning trials, and scores were submitted to a square root transformation. Again, significantly more errors were made on matching problems ($\overline{X}$ = 1.95) than on oddity problems ($\overline{X}$ = 0.16) (t = 5.11, df = 46, $p < .001$).

ID and ED test error scores were submitted to arc sine transformation, and means are reported for transformed scores. The main effect for problem for ID test errors was significant (F = 4.38, df = 1/40, $p < .05$); subjects made significantly more ID test errors on matching ($\overline{X}$ = 35.87) than on oddity problems ($\overline{X}$ = 00.00). Analysis of ED test errors yielded no significant main effects.

Analysis of the response latency measures demonstrated a significant main effect for problem type for Latency I (F =4.96, df = 1/40, $p < .05$), Latency II (F = 9.48, df = 1/40, $p < .01$), and Latency III (F = 14.66, df = 1/40, $p < .01$); subjects response latencies, although decreasing across trials to criterion, were significantly longer on matching than on oddity problems. The mean latencies for matching and oddity responding were 2.76 and 1.95, 2.23 and 2.03, and 1.68 and 1.04, for Latency I, II, and III, respectively. For Latency II, a significant main effect for dimension was also obtained (F = 4.52, df = 1/40,

$p < .05$); response latencies for color problems ($\bar{X} = 1.86$) were significantly longer than for form problems ($\bar{X} = 1.22$).

Discussion

The relative difficulty of the matching problem compared to oddity demonstrated in the performance of the college adults offered further support to the concept of a hierarchy of response strategies and the role that response strategies play in problem solving behavior.

That the subjects' response latencies, throughout training, were significantly longer for matching than for oddity problems supported the hypothesis that mediation, in this case, the suppression of the more dominant oddity response, takes time (White, 1965). No sex differences in performance was found, indicating that the order of the response hierarchy was the same for males and females and that the males and females were equally proficient in inhibiting the dominant oddity response.

It might have been proposed that in college adults the matching strategy would be as dominant as the oddity strategy and that these subjects would solve matching problems as rapidly as oddity. If solution involved simply the elimination of inappropriate strategies, there would be, perhaps, a real but small (and too small to be significant) difference in trials and/or errors to criterion between the two problems. But the model under consideration proposes that persistent matching responding involves not only the selection of the matching hypothesis but also the persistent inhibition of the more dominant oddity response. There was some indication that the relative difficulty of matching solution for the college adults was due in part to the process of strategy hypothesis testing or selection. Whereas only 7.07% of the children in Experiment I reported utilizing compound cues for solution, 12.50% of the college students reported utilizing compound cues for solution. Of course, proceeding to systematically test all hypotheses which combined oddity with any other cue (oddity-position, oddity-position-form, etc.) would result in more errors and more trials to criterion. Data also suggested that matching was more difficult for these subjects because of the requirement that subjects had to persistently inhibit the more dominant response to oddity. The percentage of subjects choosing the odd stimulus on the first trial of training was 85.41. If the first trial data was indicative of the cue salience of the odd stimulus, it would appear that not only was the oddity strategy a more dominant strategy for these subjects, but that the odd stimulus was a highly salient cue for responding. Indeed, subjects made more ID test errors on matching as compared to oddity problems. Thus, both factors - testing a larger number of incorrect strategy hypotheses following an incorrect response to oddity and inhibiting a dominant oddity strategy to a highly salient cue of oddity - probably combined to determine the relative difficulty of matching behavior in college adults.

Recommendations

The most obvious implication of the findings of the present research for educational practices is derived from the data which supported the contention that effective problem-solving behavior involves not only the development and utilization of concepts but the development and utilization of problem-solving strategies, strategies which have wide applicability in problem-solving situations. This implies that educational experiences should be directed not only toward the development of concepts but toward the development in the utilization of problem-solving strategies. The question for the child then becomes, "here is a problem for you to solve, what tools of thought, ways of behaving do you have available to bring to bear upon the problem?" Viewed in this light, the production of symbolic representational responses, the production and utilization of concepts, is but one of the kinds of tools which might facilit te problem-solving - another is the production and utilization o response strategies.

It seems quite possible that while more and more attention is being given in traditional and more progressive (e.g. "Sesame Street") educational experiences to the development of the utilization of concepts, children are acquiring problem-solving strategies in a rather haphazard manner. It would appear that these strategies would be acquired more efficiently and thus be utilized more effectively if more specific training were given. For example, as the author has observed kindergartens and first-grade classrooms in the West and Midwest, it seemed apparent that educational experiences were geared primarily to the development of concepts, and particularly, verbal mediation. Teachers seem to be aware of the information that indicates that one of the reasons that a child from a "culturally disadvantaged" background does not do well in school is that he often fails to develop adequately the ability to use language to represent various aspects of a problem-solving situation. But little attention was given to the question of the various kinds of problem-solving strategies that could be employed to manipulate those concepts for problem solution.

Of course, developmental learning psychologists have just more recently begun to investigate the various kinds of problem-solving strategies and probably only the more simple types have been identified - outcome strategies, oddity, matching, hypothesis-testing, and learning set. More research is needed to identify problem-solving strategies and then to identify the mechanisms that operate in the utilization of the strategy. For example, the present research suggested the importance of inhibitory processes, the use of internal cues for inhibiting behavior, were important factors determining matching behavior. Further, the data indicated that for certain age groups there were sex differences in the cognitive functioning in inhibitory behavior - which brings up the second important implication of the present study for educational practices.

It was proposed in the present study that the boys inefficiency in matching behavior may have been attributable to the fluctuation in their rehearsal of a strong internal cue for inhibitory behavior. If this is shown to be the case, the question arises as to why their internal control behavior fluctuated when the girls did not. It may be something as simple as that they get "bored" more quickly with tasks; it may be something much more complex, for example, that their social training is such that it encourages the establishment of fast responding patterns which puts them at a disadvantage when careful thinking, time-consuming thinking, is required. It would seem important that sex differences in cognitive functioning be a major focus of future investigations - the identification of sex differences and the identification of the factors responsible for such differences - if educational experiendes are to be planned to meet the needs of the individual student. The investigation of the question of educational practices and their possible differential effects on boys and girls, as well as on children of different socio-economic backgrounds, appears clearly indicated.

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APPENDIX A

Occupational Distribution of Subjects in Each Age Group

Occupational categories:

I. Professional and technical
II. Managers, officials, proprietors, farm managers and owners
III. Clerical and sales workers
IV. Craftsmen, foremen, and operators
V. Service workers: public and private
VI. Laborers: farm and non-farm
VII. Students and unemployed

	Categories							
Age	I	II	III	IV	V	VI	VII	Total N
5-7	16	4	3	6	0	11	0	40
8-10	9	11	6	4	1	8	1	40
11-13	9	11	6	18	3	16	1	64
College	17	9	6	3	6	6	1	46

APPENDIX B

This machine is called a Totally Automated Testing Apparatus ("filler" frame one was presented). On it, we have programmed some games for you to play. In the games, there will always be winning pictures and losing pictures; and your task is to learn how to choose the winning picture every time you choose. The pictures will come on the screen in front of you. This is how you will find out which pictures win and which pictures lose.

Look at these pictures (practice "problem" one was displayed). See the buttons below each picture? Press the button under the first picture.

Did you see the incorrect light come on? Did you hear the buzzer? The incorrect light and the buzzer tell you that that picture is a losing picture. Now press the next button under the next picture.

Did you see the incorrect light go on again? Did you hear the buzzer again? That picture is a losing picture. Now, press the last button under the last picture.

That picture was a winning picture. The bell and the correct light tell you it was a winning picture. Now, here is how you change the picture each time.

When the clown lights up, press his face and the pictures will come on again; press the clown's face now.

Look at all, all of the pictures (practice "problem" two was presented). Press the button under the first picture.

Did you hear the bell and see the correct light go on? That picture was a winning picture. Now press the next button under the next picture. The bell and the correct light tell you that that picture was a winning picture. Now, press the last button under the last picture. Did you hear the buzzer and see the incorrect light go on? That picture was a losing picture ("filler" frame two was displayed).

Remember, to bring the pictures on the screen, press the clown's face. Then you will try to choose a winning picture. Be sure you look at all the pictures before you choose. When you choose a losing picture the buzzer sounds and the incorrect light goes on. When you pick a winning picture, the bell sounds and the correct light goes on. When you have learned the game and can choose a winning picture every time you choose, you will win some prizes---some gum and candy. If you understand and if you are ready to begin the game, press the clown's face. Do you have any questions?

APPENDIX C

This machine is called a Totally Automated Psychological Assessment Console (a "filler" frame was displayed). On it, we have programmed some problems for you to solve. In the problems, there will always be correct pictures and incorrect pictures; and your task is to learn how to choose a correct picture every time you choose. The pictures will come on the screen in front of you, like this (practice "problem" one was presented).

There are buttons beneath each picture. Press the button under the left-hand picture. The incorrect light and buzzer inform you that that picture is an incorrect picture. Now press the next button under the next picture. That picture is an incorrect picture. Now press the last button under the last picture. That picture is correct. The bell and the correct light inform you that your choice of pictures was correct.

To turn the pictures on each time, press the ready button when it lights up. Press the ready button now (practice "problem" two was presented). Look at the pictures again. Press the button under the left-hand picture. That picture was correct. Press the button under the next picture. That picture was correct. Now press the button under the last picture. That picture was an incorrect choice.

Be sure to look at all the pictures before you choose (a second "filler" frame was displayed). You will probably find the problems simple; they were actually designed for younger subjects - so don't try to complicate the task; just take it for what it is and try to come to solution as quickly as possible. Try to make a correct response every time you choose. If you understand, you can begin by pressing the ready button when it lights. Do you have any questions?