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Solving Complex Perceptual Discrimination Problems: Techniques for the Development of Problem-Solving Strategies

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Techniques for developing problem-solving strategies in handicapped children when they are faced with complex perceptual discriminations were investigated. Specifically, the effectiveness of feedback, modeling, and self-instruction were compared with each other and a control condition on a specially designed matching-to-sample task. The task was designed so that the distinctive features of the stimuli could be identified for instructional purposes. The results indicated that only the self-instruction technique facilitated performance on the posttest. In addition, these skills generalized to a new set of forms but not to the Matching Familiar Figures test. These findings were further related to the development of observational skills.

An important characteristic of perceptual development consists of an increase in the child's ability to explore effectively complex stimulus configurations through organized visual scanning sequences (Reese & Lipsitt, 1970; Vurpillot, 1968; Zaporozhets, 1965). Essential to this process is the differentiation of the stimulus complex, as commonly judged by the child's ability to detect similarities and differences across a number of simultaneously presented patterns. Of course, failure to develop useful strategies for dealing with problems of this form typically presents serious difficulties for the child when he is faced with a variety of perceptual and cognitive tasks (Gibson, 1969; Kagan, 1971).

Recent investigations of the modification of conceptual tempo in so-called "impulsive" children (Kagan, 1971) may have important educational implications for children with developmental difficulties who have not developed these problem-solving strategies. This is indicated for two reasons. First, there appears to be considerable correspondence between the styles by which mildly retarded and impulsive children solve complex visual discrimination problems (Errickson, Wyne, & Routh, 1973). Second, from a developmental perspective, as Siegelman (1969) notes, the behavior of impulsive children in tasks with perceptual uncertainty resembles the cognitive behavior of younger children (see Vurpillot, 1968). Accordingly, techniques that have been successful in altering this style for impulsive children may be useful for handicapped children as well.

Cognitive style is typically measured by visual discrimination matching-to-sample tasks such as the Matching Familiar Figures test (Kagan, 1965). Children whose performance is characterized by short latencies and frequent errors on the Matching Familiar Figures test are identified as "impulsive," whereas those with longer latencies and fewer errors are labeled "reflective." Successful techniques that have produced a more reflective strategy, as indicated by a decrease in errors, have taken many forms. Errickson et al. (1973), working with mildly retarded children (IQ range [Slosson Intelligence Test], 47 to 95, mean chronological age [CA], 13.9), accomplished this simply by applying a "response-cost" procedure in which tokens associated with the purchase

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of rewards were removed contingent upon incorrect responding.

In contrast, most other successful techniques have focused on instruction designed to modify various aspects of the problem-solving process itself. In a recent study, Duckworth, Ragland, Sommerfeld, and Wyne (1974) were able to decrease errors and increase latencies of primary grade educable mentally retarded (EMR) students on the Matching Familiar Figures test following visual discrimination training. However, extended verbal reinforcement was of no additional value. Ridberg, Parke, and Hetherington (1971) prepared a film in which a reflective model demonstrated an appropriate strategy to impulsive fourth graders. This resulted in a decrease in errors, although the exact source of these changes was not apparent. Through demonstrations and explanations of appropriate search strategies and scanning methods, Egeland (1974) trained one group of impulsive second graders to solve problems correctly. A second group was provided with the same materials but was taught only to delay their responses, whereas a control group received no training whatsoever. In terms of error reduction on the Matching Familiar Figures test, only the group trained to modify their search strategies produced a durable effect.

On the basis of a wide range of developmental data relating to the development of cognitive self-guiding private speech (Bem, 1967; Kohlberg, Yaeger, & Hjertholm, 1968), Meichenbaum and Goodman (1971) compared the effectiveness of modeling with a group given "self-instructional" training. A group of impulsive kindergarten and first-grade children were taught to verbalize, first overtly and later covertly, a series of strategy steps that were first demonstrated by a model, in an attempt to provide a direct form of self-guidance. A modeling group received the same demonstrations, but self-verbalizations were not required. Part of the content of the verbalizations for both groups was based on an analysis of the literature in which they identified three possible deficiencies that could result in inadequate problem-solving behavior. First, the child may not regulate his overt behavior verbally (mediation deficiency); second, he may not spontaneously produce the relevant verbal mediators (production deficiency); and third, he may not understand the general nature of the problem (comprehension deficiency). The results showed that only the self-instruction group reduced their errors on the Matching Familiar Figures test following treatment and that their score was significantly different from both modeling and control groups. Similarly, a variation of the self-instructional procedure was successfully utilized by Guralnick (Note 1) for a group of hyperactive children.

A different but effective procedure for modifying impulsive behavior was developed by Zelniker, Jeffrey, Ault, and Parsons (1972). An experimental group was presented with a matching-to-sample task in which five of the variants were identical and only one different from the standard. The child was asked to find the one that was different. Noting the impulsive child's tendency to select a variant as identical on the basis of global similarities on the standard Matching Familiar Figures test (Siegelman, 1969), they reasoned that by requiring children to search until they located the variant that was objectively different, a useful and systematic search strategy would develop and perhaps transfer to the standard Matching Familiar Figures test. The results supported their hypothesis, with the experimental group making fewer errors than the control group on a standard Matching Familiar Figures posttest. Furthermore, corresponding eye-movement records and the fact that the reduction in errors was not accompanied by changes in latency strongly suggested that this method produced a change in search strategies.

An earlier investigation by Odom, McIntyre, and Neale (1971) regarding the nature of the information processed by reflective and impulsive children may offer a framework for interpreting the results of the Zelniker et al. (1972) study. An analysis of data in a transfer task revealed that reflective children processed and evaluated information in terms of the distinctive features or the dimensions of difference among the stimuli. In contrast, these investigators could not identify the information utilized by impulsive children. By requiring impulsive children to determine how stimuli differed, Zelniker et al. (1972) apparently succeeded in eliciting a strategy that focused some of the child's efforts on systematically determining the dimensions of difference, a very efficient search strategy for matching-to-sample type tasks (Siegelman, 1969). A follow-up study by Zelniker and Oppenheimer (1973) supported this analysis. Indeed, considerable research evidence exists suggesting that a significant aspect of perceptual development is reflected in terms of an increasing sensitivity to the dimensions of difference in the environment (Gibson, 1969) and that research designed to focus young or handicapped children's attention to these dimensions facilitates the discrimination process (Guralnick, 1972, 1975).

Taken together, these studies indicate that instructional techniques that: (a) provide direct training in the use of effective problem-solving strategies, (b) involve cognitive self-guidance, and (c) focus attention on the distinctive features of the stimulus complex are likely to be most beneficial in assisting handicapped children to solve relatively complex perceptual discrimination problems. Accordingly, the present investigation was designed to compare the relative effectiveness of various instructional methods. Specifically, the effectiveness of feedback, modeling, and self-instruction were compared with each other and a control condition on a specially designed six-alternative matching-to-sample task. This task was designed to enable the experimenter to specify clearly the relevant distinctive features of the stimuli and thereby provide explicit training with regard to identifying the critical dimensions of difference. Finally, the effectiveness of these procedures was analyzed in terms of the children's ability to generalize their skills to both highly similar problems and to the Matching Familiar Figures test.

Method

Subjects

Participants were 32 children currently enrolled in schools serving retarded children. They ranged in age from 6 to 14 years (mean CA, 11.1) and had a mean IQ of 63.2 (Peabody Picture Vocabulary Test; range, 45 to 83). All children successfully completed a series of simple matching tasks before being randomly assigned to the four treatment groups. All procedures were carried out on an individual basis.

Materials

The major task consisted of a six-alternative matching-to-sample task similar to the Matching Familiar Figures test. Stimuli were nonsense-form line drawings which varied in complexity, as defined by the number of lines per form (3 to 9). A total of 26 pairs of forms were constructed. Within a complexity restriction (see *Procedure* below), 10 pairs were randomly selected for pretesting, 6 for training, and 10 for generalization testing. The set of forms used for pretesting was also administered as a posttest, in addition to the generalization forms (see *Procedure* below).

Five pairs of opposing dimensions of difference were selected: (a) curve vs. straight, (b) open vs. closed, (c) horizontal vs. slant, (d) right vs. left (mirror image reversal), and (e) up vs. down. Forms were designed so that they could only be distinguished in terms of these critical dimensions. Accordingly, a set of rules was devised to govern the construction of each of the sample (standard) and comparison forms. First, each sample form must contain line segments that are curved, straight, opened, closed, horizontal, and slanted. In addition, the forms must be asymmetrical so as to permit an identification of up-down and right-left transformations. The purpose here was to enable transformations (e.g., open-to-closed, closed-to-open, slant-to-horizontal, horizontal-to-slant) to be carried out in both directions.

After the sample forms were constructed, five transformations of the sample and one identical stimulus were prepared as comparison stimuli. First, the sample was arbitrarily labeled "up" and "right," and two alternatives for "down" and "left" were immediately constructed. Next, one of the three remaining dimensions of difference was randomly selected as was the direction of the transformation. For example, if the curve-straight dimension was selected, then a decision (random selection) as to transforming a curved segment to a straight one or a straight segment to a curved one was made. This procedure was carried out for the remaining two dimensions, thereby generating five transformations and one stimulus identical to the sample.

The sample for the second member of the pair was the same form, except it was now oriented as "left" and "down." The remaining transformations were determined by the previous selections. The direction of change was the one not selected for the original three line-segment changes, so if an open-to-closed transformation was selected previously then a closed-to-open change was now required. The left-to-right and down-to-up transformations and the stimulus identical to the sample completed the selection of the six alternatives. Figure 1 illustrates one set of forms. The spatial arrangement and size of the forms on the figure are the same as those presented to subjects. The position of each alternative in the stimulus array was chosen on a random basis.

Procedure

Following completion of a preliminary session to ensure the existence of a matching concept, subjects were randomly assigned to one of four treatment groups: (a) self-instruction, (b) modeling, (c) feedback, and (d) control. The overall design of the experiment was to provide pretesting on the same forms for each group, administer different training procedures, and then assess the effects of training by readministering the pretest (now posttest) forms.

Generalization was evaluated in two ways. First, a completely new set of forms was presented as part of the posttest, although the dimensions of difference remained the same. Second, generalization to a completely different set of materials was assessed in the form of error scores on the

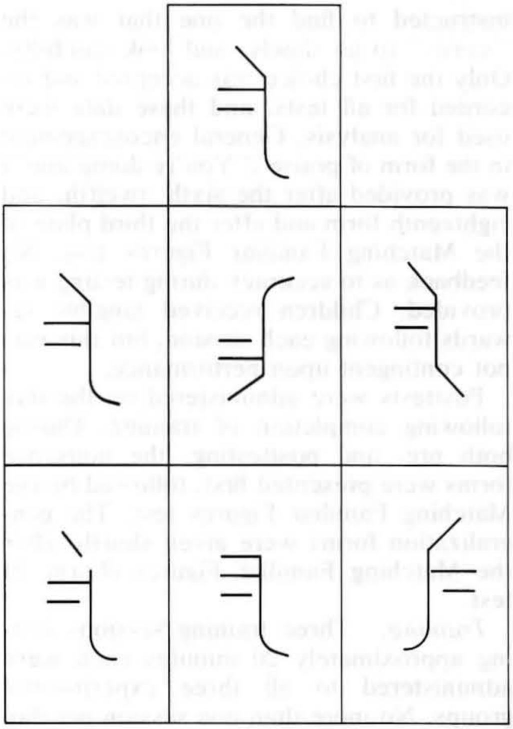

FIGURE 1. An example of the forms used in the matching-to-sample task.

Matching Familiar Figures test. The same design was used here for two alternative forms (A and B) of the 12-item Matching Familiar Figures (MFF) test (i.e., pre:MFF Form A, post:MFF Form A and MFF Form B). Alternate items of the Matching Familiar Figures test constituted the two forms. However, no intervention relating directly to Matching Familiar Figures items was provided.

Testing. The ten pairs of forms used in pre- and posttesting were ordered in terms of increasing degrees of complexity. Five sets of forms with three- and four-line elements constituted the first set, whereas three sets of five and six elements and two sets of seven to nine elements completed the ten pairs. Within each complexity level, the order of presentation of individual forms was randomized for each subject and for each testing session. The ten pairs of generalization forms were similarly ordered.

For all testing sessions, each child was instructed to find the one that was the "same," to go slowly, and look carefully. Only the first choice was accepted and recorded for all tests, and these data were used for analysis. General encouragement in the form of praise ("You're doing fine") was provided after the sixth, twelfth, and eighteenth form and after the third plate of the Matching Familiar Figures test. No feedback as to accuracy during testing was provided. Children received tangible rewards following each session, but this was not contingent upon performance.

Posttests were administered on the day following completion of training. During both pre- and posttesting, the nonsense forms were presented first, followed by the Matching Familiar Figures test. The generalization forms were given shortly after the Matching Familiar Figures (Form B) test.

Training. Three training sessions lasting approximately 20 minutes each were administered to all three experimental groups. No more than one session per day was administered.

For the self-instruction group, six pairs of forms similar to those used in testing were constructed for use in training. The general strategy, following that used by Meichenbaum and Goodman (1971), was to have the experimenter first model the problem-solving process in terms of his verbalizations (self-instructions) and corresponding motor behavior. Then, gradually over the course of the three sessions, the child was prompted to carry out and verbalize the steps, first overtly, then covertly. The verbalizations described both the specific strategy steps as well as questions and answers designed to remediate any comprehension, production, and mediation deficiencies that might exist (see Meichenbaum & Goodman, 1971, p. 117). The problem-solving strategy itself was derived from Drake's (1970) and Siegelman's (1969) analyses of reflective strategies. Essentially, children were taught first to familiarize themselves with the sample and to differentiate the critical dimensions of the stimuli by making homologous comparisons among the alternatives (the five dimensions of difference were pointed out), and then to eliminate incorrect alternatives by checking with the standard. This process was continued until all alternatives were checked. Instructions to go slowly, look carefully, and to self-reinforce were included in the self-instruction sequences.

The modeling group observed exactly the same verbalizations and behavior, except that no self-instruction training was provided. Following each demonstration by the experimenter, the child was encouraged to use the strategy.

The feedback group was presented with the same training forms as the other two groups, but no modeling of the correct strategy or self-instruction was provided. Children were simply asked to solve the matching-to-sample problems and given feedback as to their accuracy. Instructions to go slowly and carefully were given at approximately the same rate as the other groups. Since the feedback group did not require as much time for each problem as the previous two groups, various geometric forms and color matching-to-sample tasks were included. This also provided an opportunity for giving approximately equal amounts of encouragement and social reinforcement for all three experimental groups, while ensuring that each received the same number of exposures to the training forms.

The control group did not receive any training whatsoever but followed the same time sequences for pre- and posttesting as the experimental groups.

Results

A 2 (pre- and posttesting) × 4 (treatment groups) mixed analysis of variance performed on the number of correct responses during testing yielded a significant increase from pre- to posttesting ($F = 11.04$, 1/28 *df*, $p < .01$). The maximum number of correct responses was 20 (10 pairs of forms). Although no differences were found for the Treatment factor (the .05 level was used in all instances), the Treatment × Pre-/Posttesting interaction was significant ($F = 8.33$, 3/28 *df*, $p < .001$). Consequently, an analysis of the simple main effects was carried out (Winer, 1962) and revealed that the self-instruction group was the only one in which a significant increase in accuracy from pre- to posttesting occurred. A similar analysis indicated that the groups did not differ from each other during pretesting. Figure 2 illustrates these findings.

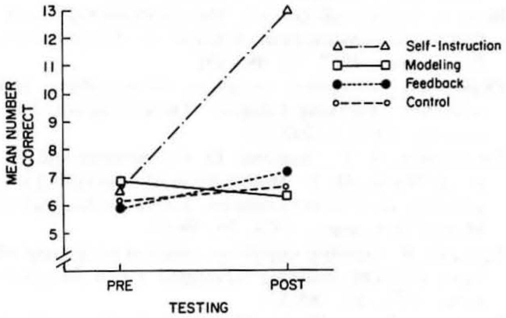

FIGURE 2. Mean number correct for each of the four treatment groups on the pre- and posttests.

A separate analysis of variance was carried out on the number correct for the generalization forms (maximum number correct was 20) and yielded a significant treatment effect ($F = 10.25$, 3/28 *df*, $p < .01$). The mean number correct for the control, feedback, self-instruction, and modeling groups were 5.75, 6.50, 13.75, and 5.88, respectively. Further analysis using the Newman-Keuls test for multiple comparisons revealed that the only significant differences were between the self-instruction group and each of the other three groups.

For the Matching Familiar Figures test (Form A), due to the fact that the data were markedly skewed, separate nonparametric Wilcoxon matched-pairs signed ranks tests (Siegel, 1956) for each treatment group were carried out on the number of correct responses to detect any pre- and posttest differences. Similarly, a Kruskal-Wallis one-way analysis of variance was performed to detect any differences among the four treatment groups on Form B of the Matching Familiar Figures test. In no instance did the results of any test approach significance.

Discussion

The results of this study clearly indicate that the self-instruction technique is an effective means of modifying the problem-solving strategies of handicapped children. Prior to their training, it appeared that subjects typically approached complex perceptual discrimination problems in a manner similar to that of younger or impulsive children. However, following sessions in self-instruction, this haphazard observing behavior was replaced by systematic search strategies resulting in a marked increase in correct responses. Moreover, these strategies generalized to problems with the same dimensions of difference as indicated by the performance of the self-instruction group on the form generalization test. However, although incidental observations suggested that these strategies were also applied to solve the Matching Familiar Figures problems, no differences among the treatment groups were noted. This may have been due to the greater difficulty of the Matching Familiar Figures test, or it may be that direct instruction in a number of qualitatively different problems is needed before a completely generalized strategy develops.

Consistent with previous research, subjects in neither the control nor feedback groups showed any changes in their ability to solve the perceptual problems. Research relating to the effectiveness of modeling has been equivocal (Egeland, 1974; Meichenbaum & Goodman, 1971), and the present results support those studies in which modeling did not facilitate performance (e.g., Meichenbaum & Goodman, 1971). This occurred despite the fact that modeling included an identification of the distinctive features and a process for systematically solving the discriminations. It appears, then, that modeling of complex strategies for solving perceptual problems of the type used here, even if properly paced, may be too difficult for handicapped children to follow. It remains to be seen if other modeling techniques can be useful in this regard.

Interestingly, a close correspondence exists between the processes involved in observational learning as described by Bandura (1969) and the components of the self-instructional technique (see Guralnick, Note 1). Specifically, Bandura's first stage is an attentional one in which the child must select the relevant cues. That selection was facilitated here by pointing out the distinctive features. In Bandura's retention phase, the child is required to utilize a representational system, usually verbal, to code and recode observed events. This process was directly taught as we verbalized our problem-solving behavior and is analogous to remediating the production deficiency previously noted. Bandura's third stage is the motor-reproduction process in which self-generated verbal instructions guide the child's own motor behavior and is analogous to the mediation deficiency. The procedure of directly instructing the child to verbalize problem-solving techniques as the problem is being solved, first overtly then covertly, may assist in developing this correspondence. Finally, reinforcement and motivational processes are activated through both external social reinforcement and statements made by the child to reinforce his own behavior. Accordingly, this correspondence suggests that the self-instructional procedure may be useful in fostering the development of observational learning, a very significant educational objective.

Finally, it may be noted that the self-instructional technique appears to be applicable to a wide range of problems (Meichenbaum & Turk, 1972; Meichenbaum, Note 2). While future researchers will hopefully identify the specific components of this process that are most beneficial, given its sound developmental framework and empirical foundation, it is likely that this method will prove to be useful for the treatment of numerous learning and behavioral problems.

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