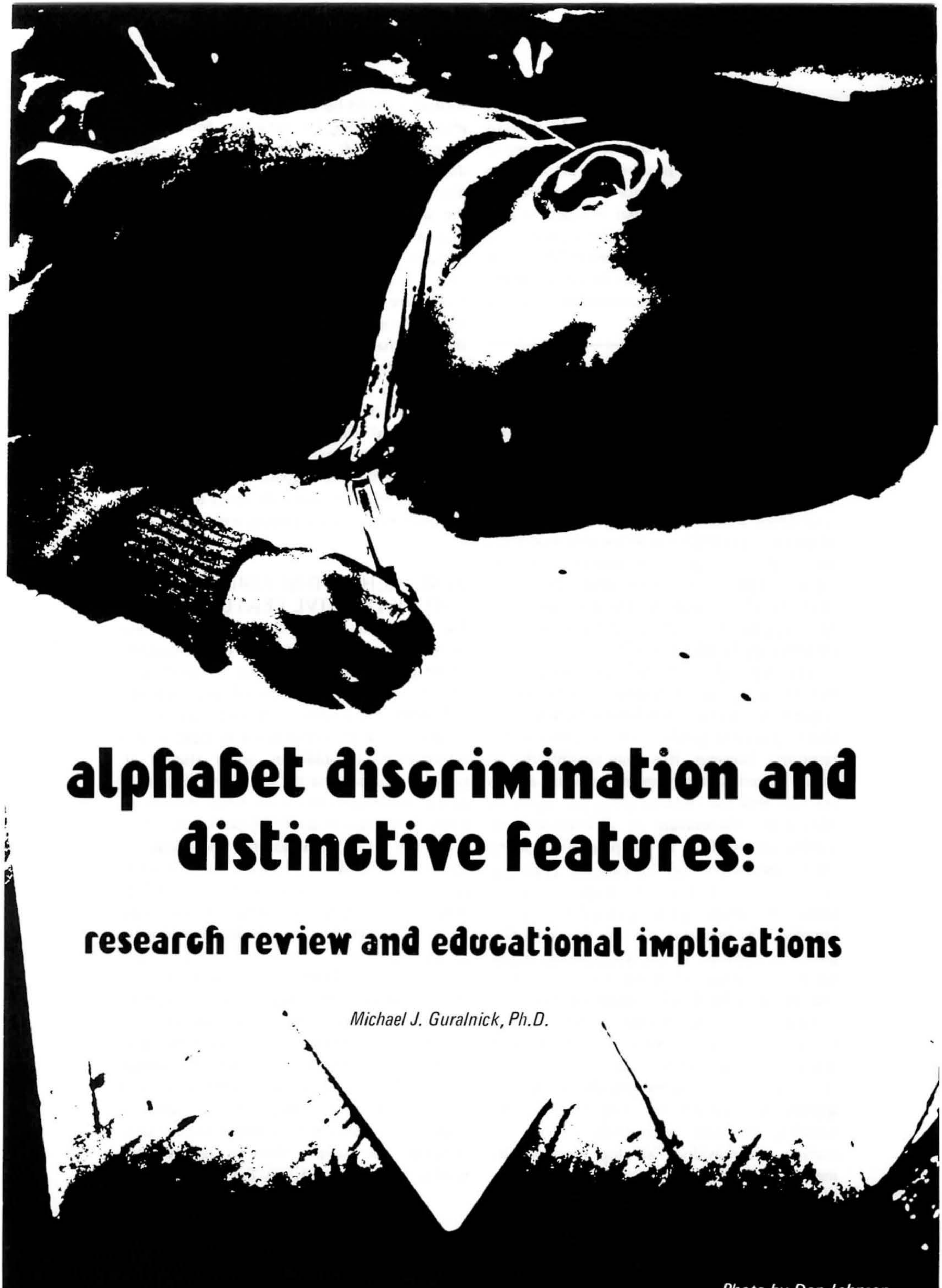

alphabet discrimination and distinctive features:

research review and educational implications

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The experimental literature relating to alphabet letter discrimination is reviewed. An analysis in terms of the critical distinctive features of the letter forms and problems in attending to the dimensions of difference are explored in detail. It was suggested that in order to best facilitate discrimination of letters, pretraining on the critical distinctive features should be provided. Specific techniques for programming the distinctive feature discriminations are presented.

The ability of children to name the letters of the alphabet is the most significant predictor of early reading skills (Bond and Dykstra, 1967). Alphabet learning is also the first real encounter with academically oriented materials for most children, and if not accomplished with reasonable ease it generally indicates the beginning of a complex series of academic and adjustment problems. For children with learning disabilities and retarded children this process is all too often a difficult and frustrating one, which probably sets the stage for the development of the negative motivational patterns recently described by MacMillan (1971).

For many children, difficulty with letter-naming tasks can be traced to a failure to acquire the proper associations between the clearly perceived graphic forms and their verbal responses. However, it is quite possible that in many instances, the problems may be due to the fact that the children are as yet unable to adequately discriminate or differentiate the graphic forms. That is, the perception of the letters themselves may be partially confused, with the consequence of producing severe confusions when verbal associations are attempted. The importance of this discrimination phase, as opposed to the associational phase, has been emphasized in the work of Zeaman and House (1963) who proposed that discrimination learning can best be understood in terms of two stages. First, individuals must discriminate and attend to the relevant dimension (e.g., color or form), and then attach the appropriate instrumental response to the stimulus correlated with reinforcement. An analysis of individual learning functions by these authors reveals that differences in performance could be accounted for by the first phase. Retardates, in particular, found it extremely difficult to attend to the relevant dimensions, but once this was accomplished discrimination performance increased at about the same rate for all subjects. Similarly, in a discussion of work linking visual memory problems to poor reading skills, Samuels (1971) notes, "The important point I would like to make here is that poor visual memory, which we know retards associational learning, reflects the fact that the subjects had not learned well in the first place and the type of learning I am referring to is perceptual learning" (p. 8). The purpose of the present paper is to review some experimental literature relevant to alphabet letter discrimination (not the associational phase) and then to suggest certain procedures based on that literature designed to facilitate the discrimination of alphabet letters.

RESEARCH ON DISCRIMINABILITY AND DISTINCTIVE FEATURES

The series of studies reviewed below was designed to assess the relative discriminability of letters. It was hoped that by identifying certain letters or letter pairs which produced a high degree of confusion, special teaching procedures could be constructed in light of this information. In addition, these studies attempted to determine the distinctive features of letters which are critical for letter discriminations. As Gibson et al. (1962) point out, "If we knew the set of such features, they could be incorporated in some of the 'reading readiness' tasks which involve visual discriminations" (p. 905). Popp (1964), in a study of lower-case letter pairs, used a two-choice matching-to-sample task with five-to-six-year-old kindergarten children. (In matching-to-sample tasks, a child is required to simply make a judgment "same" by choosing the correct stimulus, selected from a number of simultaneously presented choice stimuli, to match the sample stimulus. In most instances both the sample and choice stimuli are present until a match is made. In the delayed matching-to-sample task, however, the sample stimulus is presented briefly, then removed and the choice stimuli appear after some predetermined amount of time. The child must now select the choice stimulus which was the same as the original sample stimulus.) Confusions were the greatest among letter pairs which were reversals or rotations of one another (e.g., *b-p, d-b).* Letter pairs whose major difference was a break or close (e.g., *o-c)* showed few errors. In addition, the formal similarity of certain letters (e.g., *i-l, h-n)* apparently produced some confusions. Dunn-Rankin (1968) asked second and third-grade public school children to indicate which of two lower-case alphabet letters was most similar to a given target letter, under the assumption that the letter combinations judged most similar would be most apt to be confused. This was done for all combinations of 21 letters. On this basis, support for the confusability of letter pairs *b-d, d-p, n-u* was noted. Rotational transformations in general were rated similar (see also Davidson, 1935). Factor analysis revealed that certain structural characteristics such as short, curved letters (e.g., *a, s, e)* can be contrasted with taller, central-line dominated letters (e.g., *l, t, i).* Along these same lines, a cluster analysis reported by Gibson (1970), based on the latency and error scores of seven-year-old children and adults making a same-different judgment with combinations of nine upper-case letters, indicated that the features described as curve vs. straight, "roundness," "squareness," and diagonality are employed by individuals in making these discriminations. Similarly, Kuennapas (1966), using adults, scaled the similarity of some upper-case letters. Factors such as rectangularity, roundness, and vertical linearity emerged from his analysis. In another study, Dunn-Rankin, Leton, and Shelton (1968) focused their attention exclusively on the structural aspects of the letters. They suggested that an index of area in common among letters under axial rotation may help in predicting confusion. A factor analysis, strictly based on the scores from such an index, revealed five factors for the lower case letters. The five letter clusters were as follows: (1) *p, b, q, d;* (2) *i, f, l, j, t;* (3) *y, v, x, w, z, k, s;* (4) *n, u, m, h;* (5) *e, c, o, s, a.*

In a developmental study, Gibson et al. (1962) compared the matching performance of normal children from four to eight years old. Letter-like forms were constructed, and transformations of these forms were used as choice stimuli. The particular transformations were chosen on an intuitive basis, but were thought to reflect those characteristics of actual letters which distinguish one letter from another. The major transformation categories were line-to-curve and curve-to-line, rotation and reversal, perspective, and topological transformations, i.e., break to close. The results revealed that perspective transformations produced the largest proportion of errors which was still quite substantial even at the eight-year-old level. Errors of rotation and reversal were high for the four-year-olds but progressively decreased almost to zero at the eight-year-old level. A similar pattern was noted for line-to--curve transformations. However, break-and-close transformations produced very few errors at all ages. A partial replication of these results with the same kindergarten group two months later using actual upper-case letters provided essentially the same results. The authors suggest that the reason for improvement in matching performance with age can be traced to the fact that, through a variety of experiences, the children have discovered the dimensions of difference or distinctive features which serve to differentiate the various graphic forms. They state, "It is our hypothesis that it is the distinctive features of graphic patterns which are responded to in discrimination of letter-like forms. The improvement in such discriminations from four to eight is the result of learning to detect these invariants and becoming more sensitive to them" (p. 904). Dimensions, then, are relationships among the features of the stimulus complex, such as straight versus curve, which remain detectable in spite of variations in color, orientation, background, etc. Gibson (1969) suggests that the process by which these dimensions are detected is one of abstraction.

Following the developmental study, a more complete analysis of upper-case letter forms was carried out (Gibson, 1969, pp, 86-91; 1970). A feature chart was constructed with the particular features selected being based on a variety of neurophysiological, developmental, and experimental evidence. The general characteristics for features chosen were that they were critical for distinguishing one graphic form from another, were relational, provided a unique pattern for each letter form, and the list was economical. An error matrix was derived from a matching task using upper-case letters for prereading four-year-olds. The percent of features shared by each pair of letters was then determined from the feature chart and correlated with the confusion errors. If subjects were discriminating these forms on the basis of distinctive features, then those forms sharing many such features in common should be more difficult to discriminate whereas those sharing few features in common should not be highly confusable. This was done for each letter of the alphabet. Results indicated that 12 such correlations were statistically significant. Support for this analysis can be found in a recent study by Schiff and Dytell (1971) who assessed confusions for letters presented tactually to groups of hearing and deaf children. The confusions tended to be correlated with the percentage of visual distinctive features commonly shared by the letter pairs.

Gibson et al. (1962) hypothesized that the trends in the developmental error curves for the various transformations of the letter-like forms can be partially accounted for in terms of transfer of distinctive features learned through interactions with objects in the child's normal environment. For example, in learning the properties of solid objects, perspective transformations are not required for object identification. This holds true in many instances of object identification where objects are either rotations or reversals of one another. Presumably, the relatively high error curves for perspective, rotation, and reversal transformations reflect the lack of relevance of these dimensions for object identification.

In partial summary, experimental analysis has suggested that the discrimination of graphic forms depends on the individual becoming sensitive to the critical distinctive features or dimensions of difference which characterize these forms. A training program specifically designed to teach children to attend to these features should be valuable in increasing discrimination skills, and eventually naming of letters in the alphabet. This should be especially true for retarded children whose lack of skill in attending to or detecting the relevant features of a stimulus display appears to be the most important aspect of their discrimination learning deficit (Zeaman and House, 1963). Although a number of such procedures will be described at a later point in this paper, a considerable amount of work has been carried out in the area of orientation discrimination and will be briefly reviewed below. The general method of these studies is to first provide some form of pretraining on the orientation dimension and then to evaluate the effects of this discrimination pretraining on some type of transfer task.

PRETRAINING: ORIENTATION

The perception of orientation by children has recently received considerable attention, probably because, as noted above, errors of rotation and reversal are extremely prominent, especially mirror-image type reversals. Jeffery (1958), working with three-and-four-year-olds, found that children who were initially unable to attach differential verbal labels to differently oriented (left-right) stick figures were able to do so following training in which buttons were pressed which corresponded to the two orientations. Motor pretraining, then, facilitated the learning of verbal labels. Similarly, Hendrickson and Muehl (1962), in their study of kindergarten children, found that specific training of directional cues of the letters *d* and *b* facilitated transfer to a paired-associate task involving these letters, in comparison to a control. A consistent motor response, as used by Jeffrey (1958), did not appear to be necessary and attentional factors were stressed. In fact, as Samuels (1971) has noted, these studies would now be interpreted in terms of the relationship between attentional factors and distinctive features. Williams (1969), working with kindergarten children, found that delayed matching-to-sample pretraining on the discrimination of letter-like forms, in which the comparison stimuli were transformations of the standards (right-left, up-down, 90°, and 180° transformations), produced superior discrimination performance in comparison to a group in which the comparison stimuli were different forms. Caldwell and Hall (1969) were able to produce a substantial decrease in confusion errors for the letters *d, b, q, p,* also with kindergarten children as subjects. This was accomplished by using overlays of nonsense forms in pretraining and requiring the children to match a standard to a choice of stimuli varying in orientation. A correct match required attention to the orientation dimension. Teaching this "same-different" concept with orientation relevant was successful in producing very few confusion errors using letters in the transfer test. A second group which also used the overlay method but could rotate it to produce the correct match, thereby making orientation irrelevant, performed very poorly – in fact, more poorly than a control group who were pretrained on the task with only form and size differences. Koenigsberg (1971) attempted to determine exactly what components and characteristics of these pretraining procedures are necessary to produce a positive effect with respect to orientation discrimination. Procedures such as superimposition of standard and comparison, tracing, observation of superimposition, etc., were tested with preschool children. The results indicated that demonstrations of the orientation differences were sufficient to produce the positive effects. However, this effect is unlikely to occur for children who have any significant learning difficulties or a history of infrequent reinforcement for attending behaviors. Bijou (1968) devised a program, using the matching-to-sample technique, to first teach subjects to select a correct form irrespective of its orientation and then to distinguish rotated matches from rotated mirror-images. This program was successful for both young children and retardates. Of special note, experience in this task facilitated mirror-image discrimination to new nonsense forms as well as to alphabet letters.

Clearly then, at least for the orientation dimension, various types of discrimination pretraining can have positive effects. However, in the studies reviewed, the transfer task was often quite different in either its stimulus or response aspects from the pretraining task. For children with learning disabilities and retarded children this difference is often so large that transfer does not occur. Bijou's (1969) study differed from these others in that training was an essentially continuous process, from the introduction of the child to the apparatus to the presentation of the mirror-image stimuli.

PROCEDURES

Programing: Careful programing in small steps, designed and redesigned in terms of the behavior of the subjects with immediate feedback are, of course, some of the characteristics of what is referred to as programed instruction (Glaser, 1965). In work on discrimination learning with children, the value of such programing has been amply demonstrated (Hively, 1962; Sidman and Stoddard, 1967). The two studies noted below provide a basic model of this programing process. In both instances the emphasis is on maintaining correct performance with reinforcement and feedback by starting with an easy discrimination and gradually moving toward a more difficult one. Sidman and Stoddard (1967) utilized a fading program to teach severely retarded boys a circle-ellipse form discrimination. Fading refers to two types of procedures (Terrace, 1966). First, after a correct response has been established to a given, usually easier, stimulus in a discrimination task, a new and usually more difficult stimulus may be presented – for example, by either superimposing it onto the original stimulus or placing it beside that stimulus. The new stimulus is faded-in in small steps of increasing saliency so as not to disrupt the original performance. The second procedure refers to the fading out of the originally easier stimulus so that correct responding will eventually require the child to make the more difficult discrimination. In the Sidman and Stoddard study, a group was provided with a series of steps designed to transfer stimulus control from an easy discrimination to the more difficult circle-ellipse discrimination. The program first required the subjects to make a simple brightness discrimination. This brightness dimension was then faded out, requiring a form-no form discrimination (circle present vs. no form). Finally, ellipses were slowly faded in and the subject had to base his responses on the forms themselves in order to obtain reinforcement. A test group was not provided with this pretraining, but was given the criterion form discrimination task to be learned by trial and error at the outset. Under these conditions, the test group did not perform nearly as well as the programed group. A detailed analysis of the error patterns of subjects revealed that these patterns could be accounted for by the structure and reinforcement contingencies found in the task. In fact, the analysis suggested that the error patterns produced by the test group on the circle-ellipse discrimination were extremely resistant to change, even when those subjects were given the programed series.

Hively's (1962) programing technique is designed for matching-to-sample tasks. In this program, for two choices, the sequence is divided into four main series. In the first series no incorrect choice is available and the matching stimulus is placed directly below the sample stimulus. When stimulus A is used as the sample it is always placed on the left; when stimulus B is the sample it is always placed on the right. The second series consists of presenting both choice stimuli, still in the same positions, with the correct choice always to be found directly below the sample stimulus. In the third series, the sample stimulus is placed in the middle position, although the choice stimuli still remain in a fixed position depending on the sample (i.e., if sample stimulus is A, choice A is found on left, if B sample, B choice found on right). Finally, in series four, the position of the choice stimuli varies from trial to trial. A transitional segment between series one and two is employed to fade-in the second choice stimulus. This is done in four steps of intensity until equality is reached. A two-step transitional segment is also used between series two and three. The sample stimuli are moved in two steps from a point directly above the correct choice stimulus to midway between the choice stimuli. As noted, the child progresses from an easy discrimination in series one (no incorrect choice available with the correct choice directly below the sample stimulus) to a discrimination in which no cues are available except those provided by the stimuli themselves.

Distinctive Feature Training. If one were to use, say, the Hively program as a means of presenting an alphabet letter discrimination in a matching-to-sample task, there is, of course, no guarantee that the appropriate letter discriminations will result, even though the structural aspects of the programing procedure have been carefully designed. It is quite possible that the letter stimuli themselves are too complex or too similar perceptually, so that the child will not perform at better than chance level at series four. In light of the discussion earlier in this presentation, it is reasonable to suggest that in this case the child has failed to detect and attend to the distinctive features which characterize the differences among the letters. The same programed procedure can thus be used, not to present the letter stimuli themselves, but instead to teach the child to discriminate the critical features, as has been carried out for the orientation dimension. After this has been accomplished, the children can be gradually transferred to letter discriminations. In addition, Samuels (1971) has suggested that a delayed matching-to-sample procedure be used before letter naming tasks are introduced in order to facilitate memory for the distinctive features.

Although work on the analysis of the distinctive features of graphic forms is not complete (the following discussion is limited to upper-case letters), three types of features seem fairly well-established (Gibson, 1969). These are: (1) break vs. close, (2) curve vs. straight line, (3) diagonal vs. horizontal line (relative diagonality). The discrimination of the letter pair *C-O* obviously requires the break-vs.-close discrimination and is one which is generally acquired early in development (Gibson et al., 1962). However, many children find this discrimination difficult. To facilitate its occurrence, a matching-to-sample task using the Hively program is suggested. The stimuli would consist of two straight lines, one broken and the other completely connected. The child would be required to discriminate the broken line from the complete one. Initially the size of the break in the line would be quite large but the gap would be progressively decreased as the child successfully made the discrimination. If the line gap was not detected initially the gap could be filled by, say, a blue line to make the discrimination much easier. Then, the blue line would be faded out requiring the break-vs.-close discrimination and not the color discrimination to be made for a correct response and reinforcement.

After being successfully trained in this discrimination, the child may be given the *C-O* pair. However, it is possible that transfer to these letter stimuli may be too large a step. In that event training on the break-vs.-close dimension using other forms, which are more complex such as triangles, squares, etc. – with the break in different positions, should be given. The intent here is twofold. First, using other forms gives the child more practice and requires eye scanning to different points on the forms to detect the gap. Second, by giving a number of different examples, a "learning-set" or "concept" of break-vs.-close may be established. This procedure may be extremely beneficial for other types of visual discriminations as well.

The curve-vs.-straight dimension which characterizes the *D-O* or the *V-U* difference, is a critical one, yet often difficult. It is suggested that a procedure similar to the break-vs.-close dimension be applied here; starting with two lines, one straight, the other with a large curvature, and eventually reducing the curvature when the child performs well. Other lines at various orientations should also be part of the program as well as curved versus straight forms, such as an ellipse versus a rectangle.

Whether a line is horizontal, vertical, or has some degree of diagonality is clearly a critical dimension for the discrimination of a large number of letters. This can perhaps be most easily seen in the *H-N* discrimination, although these letters also differ in that *H* has a symmetrical component not shared by *N* (Gibson, 1969, p. 88). Training children to discriminate a horizontal from a vertical line as well as horizontal from vertically oriented forms is generally not difficult to accomplish. However, as has been noted above, other orientations such as a diagonal versus a horizontal or vertical line may prove to be more difficult. Again, a similar type of training sequence is recommended. First, the horizontal-vertical discrimination should be established with a variety of forms and then the diagonality of one of the lines (then the forms) should be gradually increased. Diagonals in both directions should be employed. Bijou's (1968) matching-to-sample program should be consulted for mirror-image stimuli.

Detecting the fine detail of a graphic form, such as the addition of a component, is, of course, necessary for a number of letter discriminations, such as *O-Q*, *P-R*, and *G-C*. A fading program lends itself nicely to this type of discrimination. Differences between forms can be exaggerated and then slowly reduced as correct discrimination performance is maintained. It is important to note that errors should not be permitted to occur to any great extent. Research has clearly indicated, especially for these types of tasks, that if a substantial number of errors does occur, the individual has learned to respond to a variety of irrelevant task or stimulus characteristics which become highly resistant to change (Hively, 1962; Sidman and Stoddard, 1967; Touchette, 1968). If errors do occur, the child should be returned to the simpler discrimination and given more training. In fact, a fairly stringent criterion should be met by the child at each level of discrimination difficulty (e.g., degree of detail exaggeration, size of the gap, extent of diagonality, degree of curvature, complexity of stimulus form, etc.). In cases where the final step to the letter discrimination is producing some difficulty, even though the child has had extensive pretraining experience, a technique of highlighting the distinctive feature or features may be needed. The use of thick lines, colors, or size differences, which must ultimately be faded out, may be of value here.

Although these procedures may, on the surface, appear to be quite tedious and time consuming for the instructor, the fact is that in the long run a considerable amount of time and effort is likely to be saved. The materials themselves are fairly easy to construct and simple to score. Since they can be scaled in terms of difficulty, a child can be placed at a particular level of distinctive feature training depending on the types of errors he makes and then gradually brought up to specific letter discriminations.

Interestingly, little research has been carried out on distinctive feature training and alphabet discrimination with other than the orientation dimension. Nevertheless, a sufficient experimental and theoretical literature does exist, based on distinctive feature theory and the powerful stimulus programing techniques, to warrant an extrapolation of these principles to other features; and I have confidence that future research will bear this out. This reasoning has formed the basis for many of the suggestions for training found in this paper. It is hoped that an application of the techniques suggested here, which emphasize perceptual learning for learning-disabled and retarded children, will greatly facilitate the learning of letter names and eventually letter-sound correspondences. — *National Children's Center, 6200 Second St., N.W., Washington, D.C. 20011.*

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