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A DEVELOPMENTAL STUDY OF THE DISCRIMINATION OF LETTER-LIKE FORMS[1]

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It has generally been assumed in psychological analyses of the reading process that ability to discriminate letters is a prerequisite for reading and that children of 6 yr., when they begin to read, can in fact distinguish one letter from another with reasonable accuracy. The relevant literature is summarized by Vernon (1957, pp. 20 ff.). Some studies have used drawing as a criterion, some naming, and some matching. No one study has traced the development of letter differentiation as related to those dimensions or features of letters which are critical for the task and which may present more or less difficulty.

A method of studying this problem was suggested by an experiment of Gibson and Gibson (1955) in which children of two age groups and adults identified "scribbles" which were systematically varied on three separate dimensions (number of coils, compression, and orientation). The scribbles were somewhat comparable to strokes used in cursive writing. The results showed that the difficulty of the task was greater the younger the *S*, that errors varied in number with the dimension varied, and that systematic variation along at least three dimensions was possible. It also showed that confusion errors (primary generalization) provided an effective criterion for measuring ability to differentiate line drawings of this type.

The present experiment was designed to study the development of the ability to discriminate visually a set of letter-like forms in children 4 through 8 yr. of age. The aim was not merely quantitative comparison of different age levels, but primarily a qualitative developmental study of types of error as related to certain critical features of letters.

To secure information on qualitative changes, the plan was adopted of constructing specified transformations for each of a group of *standard* letter-like forms. The transformations were chosen on an intuitive basis with regard to the distinctive features of letters as a set. Three types of transformation were included which were considered critical for discriminating printed letters, and one which was not.

Letter-like forms were selected, rather than actual letters, in order to keep specific experience with the forms as equal as possible. Matching, rather than identification, was the task, since simple discrimination (seeing a difference) was the criterion desired.

METHOD

Materials

Construction of standard forms. An analysis was made of actual letters (printed capitals, upper case, of the simple type customarily used in primary texts) in terms of number of strokes, straight vs. curved lines, angles, open vs. closed forms, symmetry, etc. This procedure provided a set of "rules" which describe generally the construction of letters. New forms were generated which follow the same constraints. A large number of forms resulted from which 12 were chosen as standards for the experiment. Of these half were symmetrical and half asymmetrical, half open and half closed, some combined straight and curved lines, some were composed only of straight lines, some only of curves, and the number of strokes varied from two to four. The standards are pictured in the first column of Figure 1.

Construction of transformations. The transformations chosen were as follows: three degrees of transformation of line to curve or curve to line (*1*, *2*, or *3*); five transformations of rotation or reversal, i.e., 45° rotation, 90° rotation, 180° rotation, right-left reversal, and up-down reversal; two perspective transformations, a 45° slant left and a 45° backward tilt; and two topological transformations, a break and a close.

The transformations are pictured in Figure 1 in the columns from left to right, each one in the same row as its standard. They were constructed by a draftsman, tracing from the standard whenever possible so that no change other than the intended one would be introduced. The perspective transformations were made by photographing each standard at the desired slant or tilt. The copies to be used for the experiment were reproduced by a photostatic process from the master copies. They were then mounted on 1¼-in.-sq. cards and covered with plastic.

It will be noted that half the forms (the symmetrical

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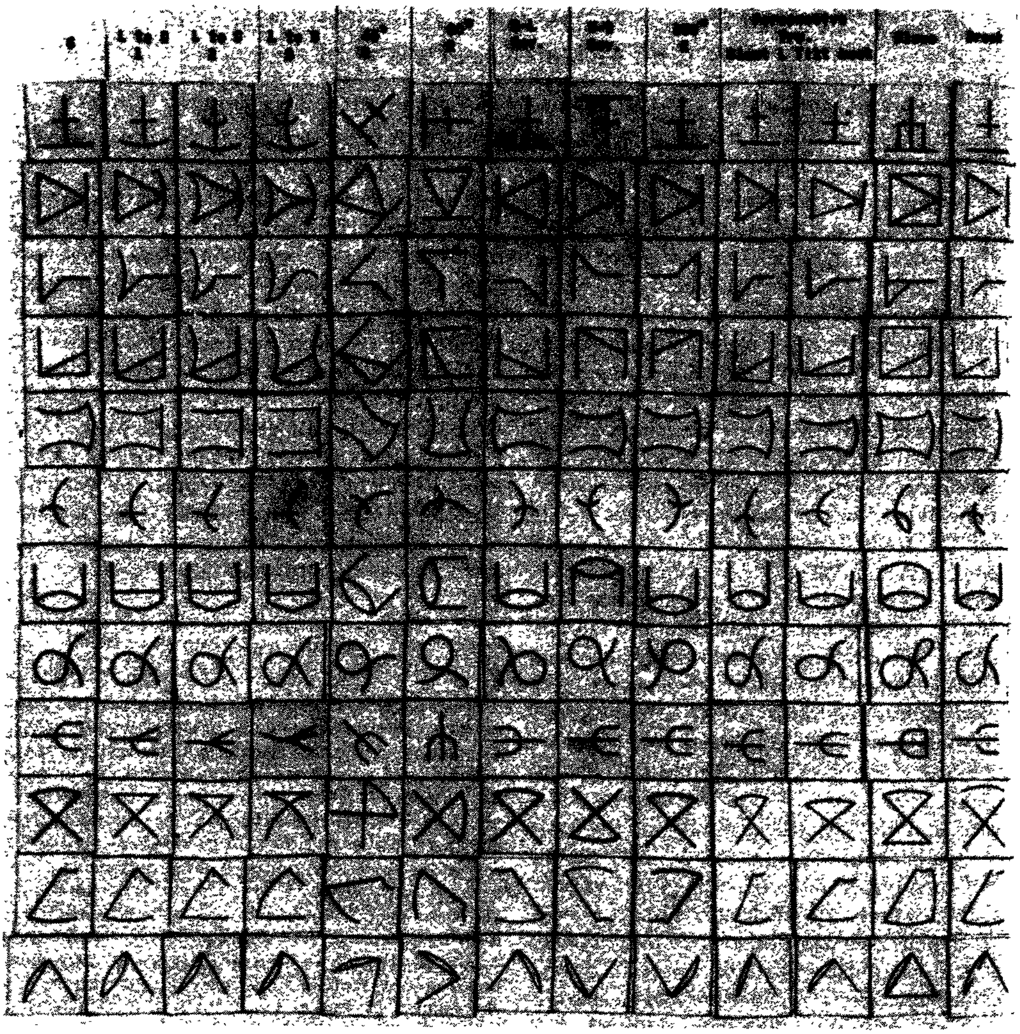

FIG. 1. The standard forms and their transformations.

ones) lacked two transformations, since either the right-left reversal or up-down reversal was identical with the standard and the 180° rotation was identical with the other. The cells in these cases were filled with the standard.

Procedure

The task. The discrimination task required *S* to match a standard with an identical form, in the following manner: A standard form was placed in the center of the top row of an apparatus which might be thought of as a matrix board (see Fig. 2). It was constructed of black-painted wood and contained four slotted rows below the top one, tilted so that *S*'s angle of regard would be the same for each row. Each row held 13 cards. In any single row, a given standard and its own transformations were placed in a random order. Three boards were available, so that 12 rows, one for each standard and its transformations could be set up before the experiment began. For the forms which lacked two transformations, three copies of the standard were mixed with the transformations. The others had one copy each of the standard in the row. This unequal number of exact matches per row had the advantage of preventing *S* from finding one and then stopping without scrutinizing the other cards.

After *E* had put the appropriate standard in the center of the top row, *S* went through a given row searching for any form which was "exactly like the standard." When he found one, he removed it and handed it to *E* and continued until he had scanned the entire row. The display on the board at any given time had four filled rows, except for spaces left where *S* had

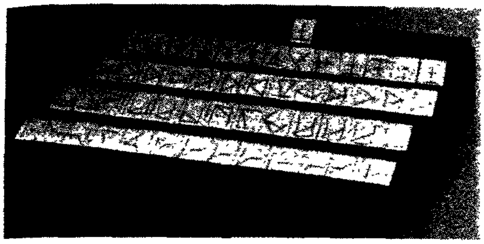

FIG. 2. Apparatus for displaying forms in the matching task.

removed a presumed match All Ss matched for all 12 standards in counterbalanced orders.

The instructions were given very explicitly, so as to make absolutely clear that only an exact match was wanted. A demonstration was given first with very large sample forms (real letters) which included two reversals. The *E* asked if they were the same and corrected *S* if he responded incorrectly. Repetition and other terms such as "equal" or "exactly like" were used if necessary. Then *S* was given a practice row on the matrix board, again with real letters, but with a standard at top and filled board so that conditions simulated the final task. The *S* scanned across the row indicated by *E*, matching the standard, and *E* corrected his errors and explained the task again, if needed. If *S* lost his place or seemed not to be looking at every letter, his regard was directed across the board by *E*'s indicating each one in turn. His attention was recalled to the standard if errors were made. No correction was given after the main task was begun, but the younger children had their attention directed back to the row and were guided across if their gazes wandered. There was no time limit.

Scoring. When *S* withdrew a form from the board and gave it to *E*, it was filed in a box and later classified as a correct match or an error. An error could be of two kinds: (*a*) failure to recognize a standard or (*b*) a confusion error, that is, selection of a transformation as identical with a standard. In the latter case, errors were classified according to type of transformation.

Subjects

The *S*s were 167 children aged four through eight. The *S*s from kindergarten through third grade were obtained at the same school, where the experiment was run during school hours. When grades were grouped according to progress, samples were taken from each group. The younger children were obtained at three nursery schools, the Cornell University Nursery School, a church nursery school, and a public nursery school at a settlement house. Numbers varied somewhat for age groups, but each age group contained at least 24 *S*s, in order to rotate twice through the order.

Validation Experiment

It seemed desirable to have a check on the validity of the "letter-likeness" of the forms as well as a replication of the transformations with other standards. For this reason, a second experiment was run in which the standards were 12 real letters (roman capitals, of the type used to formulate the rules in the first place). The 12 transformations were the same as those of the main experiment, and the material was constructed in the same way (see Fig. 3). The task and the apparatus duplicated the first experiment.

The *S*s were the kindergarten children tested in the main experiment, except for two who were no longer available. There was a 2-mo. interval between experiments.

RESULTS

Order Effects

A check was made to see whether order (position of the standard in the series of 12) was a source of variance. By Tukey's test of differences among a group of means (see Ryan, 1960), no difference was significant. Order was therefore disregarded thereafter and the data were combined.

Pooled Errors by Age Groups

There were very few errors of omission (failure to select the true match)—these errors did not vary in any orderly way, as Table 1 shows; therefore, all further discussion will be concerned with confusion errors, that is, identifying a variable as a standard. Pooled mean errors of this latter type declined with age, as would be expected (see Table 1). The standard deviations indicate rather large individual differences, which also decreased with age except for the 6-yr.-olds, who were apparently an unusually heterogeneous group. The drop in mean error from 5 to 6 yr., furthermore, was not as great as that between other age groups. The difference in mean error between boys and girls was small for all five groups, favoring the girls through 6 yr. and then the boys.

Analysis of Errors by Transformation

The mean errors for each type of transformation, presented in Table 2 for the five age groups, differ in frequency for different transformations as well as for age groups. There was a decrease in errors for all transformations as age increased, but some transformations were harder to discriminate from the standard than others, and rate of improvement varied with the type of transformation.

The errors for both the topological transformations—the changes of close and break—were few even for the 4-yr.-olds and declined

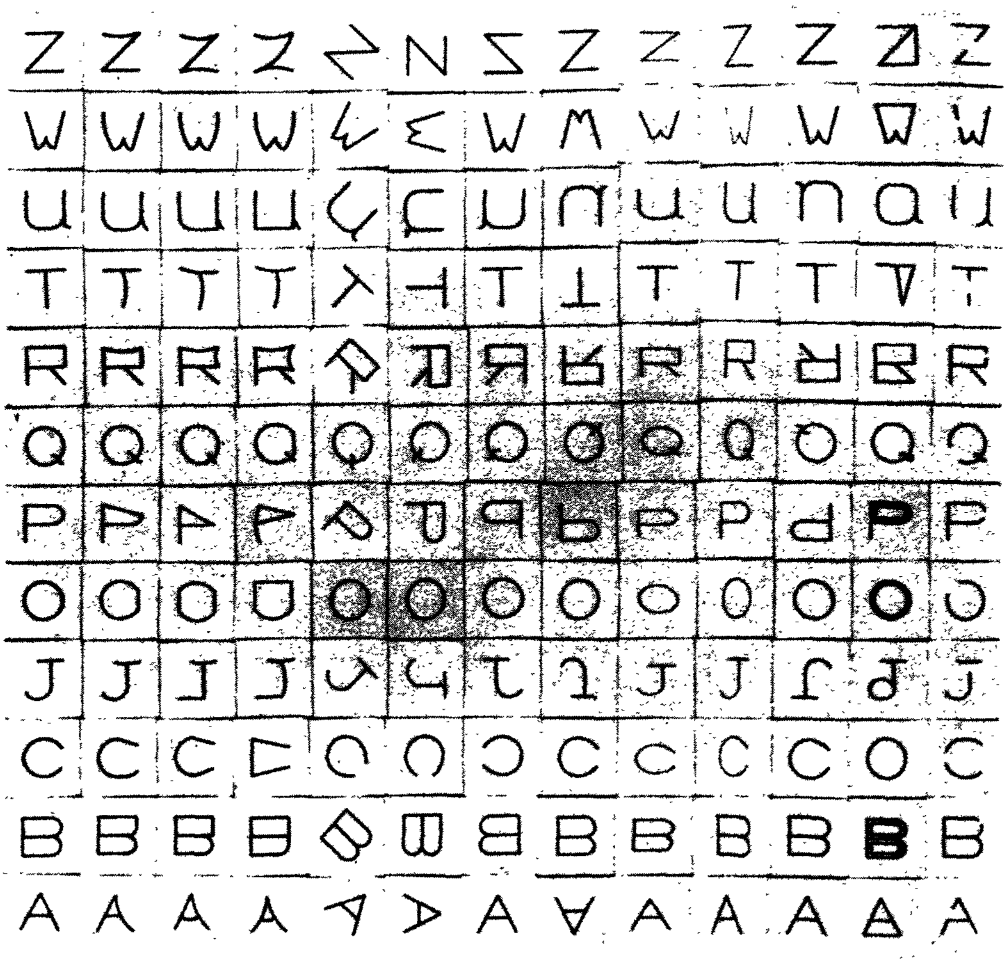

FIG. 3. Real letter standards and their transformations.

to almost zero for 8-yr.-olds. For both perspective transformations, on the other hand, the errors started very high (M = 9.88 and 9.23 at 4 yr., out of a possible 12), and were still high at 8 yr.

The errors for rotations and reversals started high, but by 8 yr. had declined almost to zero.

The errors for changes of line to curve were relatively great at 4 yr. for the first degree transformation and dropped low by 8 yr. For these transformations, mean error varied with the number of changes. Gradients of generalization for the three degrees of transformation can be compared by age groups. Generalization was greater, the younger the child, except for the overlapping of 5- and 6-yr.-olds, and in every case decreased as the degree of change increased.

The differences in development of discrimination depending on type of transformation are most easily seen in Figure 4. Errors were combined for each of the four transformation groups. The curves not only look different from one another but the differences are statistically significant at most points of comparison. Ryan's (1960) method for making multiple comparisons was applied to proportions of errors to test the differences between the four types of transformation. At age four, all the differences were significant, and at five, six, and seven, five of the six differences were significant. At eight, where errors were few the

TABLE 1

Pooled Mean Errors by Age Group

Measure	Age				
	4	5	6	7	8
N	26	35	29	30	32
Omission errors	1.31	1.83	.41	.87	.94
Confusion errors					
Boys	61.69	40.42	37.76	24.53	16.63
Girls	54.54	38.31	36.25	27.85	22.88
M	58.12	39.46	37.14	25.97	19.75
SD_M	25.39	20.75	23.20	11.00	10.95

TABLE 2

Mean Errors Made for Each Transformation by Age Groups

Transformation	Age Groups				
	4 (N = 25)	5 (N = 35)	6 (N = 29)	7 (N = 30)	8 (N = 32)
Curve to line (1)	5.85	4.06	4.00	2.53	1.28
Curve to line (2)	4.42	2.60	2.69	1.33	0.53
Curve to line (3)	3.04	1.46	1.76	0.60	0.31
45° rotation	5.19	2.14	1.79	0.53	0.78
90° rotation	4.31	1.48	1.28	0.03	0.34
Right-left reversal[a]	6.56	3.96	2.07	0.97	0.59
Up-down reversal[a]	6.47	3.55	2.44	1.56	1.08
180° rotation[a]	5.24	2.74	1.10	0.14	0.38
Perspective, hor.	9.88	9.20	9.69	9.27	7.34
Perspective, vert.	9.23	8.97	9.31	8.20	6.81
Close	1.19	.69	0.83	0.43	0.31
Break	2.62	1.86	1.86	1.07	0.59

[a] These figures have been corrected to allow for the fact that opportunities for error were less than for the other transformations

differences were significant only between perspective transformations and the other three types.

The slopes of the four curves suggest that there is the greatest developmental change between 4 and 8 yr. in tendency to confuse rotation-reversals, with line-to-curve errors showing the next greatest drop, perspective errors next, and topological errors least. To test the differences in drop in error with age, the two youngest age groups were combined and the two oldest combined and the mean amount of drop computed for each type of transformation. Then t tests were made of differences

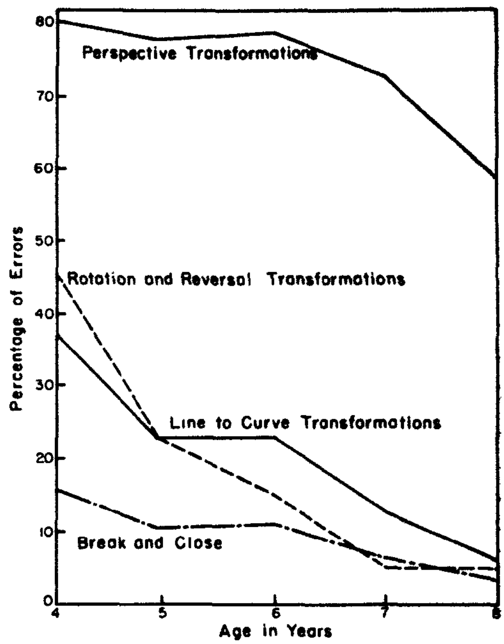

Fig. 4. Developmental error curves for four types of transformation.

between these mean drops for all six transformation comparisons (see Table 3). The difference in error decrease between perspective transformations and topological transformations is not significant, but all the other differences in slope are valid.

Correlations between Types of Error

With reference to the four curves of Figure 4, some justification should be given for pooling errors within transformation groups. There

TABLE 3

Comparison of Mean Amounts of Drop in Error for Different Transformations

Transformations Compared[a]	Difference in M Drop	t
TT-PT	0.92	1.12
TT-CL	5.18	7.01*
TT-RR	10.94	7.03*
RR-PT	10.22	5.94*
RR-CL	5.81	4.57*
CL-PT	4.25	4.29*

[a] TT = topological transformations; CL = curve to line transformations; RR = rotation and reversal transformations; PT = perspective transformations.

* $p < .01$.

were several reasons for so doing: First, ad hoc or intuitive reasons, because the transformations combined were of the same geometrical types and because the curves, when drawn individually, resembled each other within transformation groups. Furthermore, the differences between curves of *different* transformation groups were overall significant. It was also possible to obtain a third kind of evidence, i.e., the intercorrelations between different kinds of transformation error.

Correlations were run between errors for each of the 12 transformations and every other, separately for each age level. This gave a 12 × 12 correlation matrix for each age level. Because space does not permit printing all the five matrices, the information yielded by the correlations is summarized in Table 4. The correlations *within* a transformation group, where there is more than one, have been averaged. So have the correlations between that transformation group and all others. For instance, the mean correlation between the three line-to-curve transformations is +.88 for the 4-yr.-olds, but the mean of the line-to-curve transformations with other types (rotations, reversals, perspective transformations and topological transformations) is lower, +.62. A similar comparison can be made at each age level for each transformation group. The N in Table 4 refers to the number of correlation coefficients which have been averaged for any mean in the column. (The S N is always the same for any age group.) Ranges are presented under the means in brackets to indicate the lowest and highest of the coefficients averaged in any mean.

It will be noted that in 18 of the 20 comparisons within and between transformation groups, the mean correlation is lower between different transformation types. In the two atypical cases (rotation-reversal and topological transformations at the 7-yr. level), the correlations are low and insignificant. The reason for this is that errors of these types had dropped to zero for nearly all *S*s. The correlations for the 7- and 8-yr.-olds are less meaningful than those at four, five, and six because of the lowness of the error scores for everything except perspective transformations. The topological transformations showed less contrast than the others, probably because they are not as "clean" transformations. The break or the close had to be inserted somewhat arbitrarily, so that configurational changes in addition to the desired one probably resulted in some instances.

The high intercorrelations between transformations of the same type furnish strong supportive evidence for the inner consistency of the types of features chosen for qualitative analysis of errors.

Comparison with Real Letters

A check on validity, both of the material used and the functioning of the different transformations, was furnished by the repetition of the experiment with 12 real letters and the same 12 transformations. Only the kindergarten group took part. In Table 5 the mean

TABLE 4

MEAN CORRELATIONS WITHIN AND ACROSS TRANSFORMATION GROUPS

Age	L to C		R & R		P.T.		T.T.	
	Within $N = 3$	Across $N = 27$	Within $N = 10$	Across $N = 35$	Within $N = 1$	Across $N = 20$	Within $N = 1$	Across $N = 20$
4	.88	.62	.77	.54	.73	.43	.59	.52
	(.85 to .91)	(.32 to .81)	(.63 to .91)	(.28 to .81)		(.25 to .59)		(.25 to .75)
5	.76	.55	.74	.43	.68	.33	.65	.52
	(.71 to .83)	(.29 to .85)	(.61 to .87)	(.01 to .73)		(.01 to .53)		(.28 to .85)
6	.90	.54	.78	.42	.85	.40	.55	.48
	(.87 to .93)	(.37 to .88)	(.64 to .95)	(.18 to .66)		(.15 to .60)		(.15 to .88)
7	.70	.22	.07	.14	.81	.26	−.19	.17
	(.66 to .77)	(−.19 to .79)	(−.20 to .38)	(−.17 to .50)		(−.15 to .57)		(−.19 to .79)
8	.58	.46	.77	.34	.75	.35	.48	.18
	(.45 to .73)	(.04 to .73)	(.60 to .97)	(−.05 to .74)		(−.05 to .53)		(−.03 to .45)

TABLE 5

MEAN ERRORS BY TRANSFORMATION FOR LETTER-LIKE FORMS AND LETTERS, AND THE CORRELATIONS BETWEEN THEM

Transformation	*M*		Correlation between Forms and Letters
	Forms	Letters	
Curve to line (1)	4.33	4.25	.56
Curve to line (2)	2.78	1.98	.37
Curve to line (3)	1.60	1.15	.42
45° rotation	2.48	1.18	.84
90° rotation	1.90	1.18	.84
R-L reversal	3.33	2.25	.77
Up-Down reversal	2.93	1.03	.75
180° rotation	1.53	.65	.75
Perspective, hor.	9.38	7.85	.49
Perspective, vert.	8.95	7.13	.37
Close	.88	.68	.63
Break	1.85	1.23	.59

number of errors for each transformation can be compared for the letter-like forms and the letters. Errors were fewer for letters. This trend might be expected, since the children were familiar with letters (they could print their names) and they were 2 mo. older. But the correlations between transformations are are significant in every case.

One can also ask whether the order of difficulty of transformations corresponds in the two cases. The rank-order correlation between the forms and the letters, ordering the transformations according to mean number of errors, is +.87, showing that there was high correspondence.

Correlations within transformation types and across them were obtained for the letters, as they were for the forms. Mean *r*'s within transformation groups were .83, .76, .73, .73; between groups, .56, .44, .38, .53. As was the case with the forms, the correlations within groups were considerably higher than across groups.

These results appear to confirm very satisfactorily the qualitative differences produced by different transformations in the first experiment. From this evidence, it is concluded that transformation type is a good predictor of confusion errors.

Comparison of Forms

Although characteristics of the individual standard forms were not a matter of primary interest for the experiment, it is possible to classify and compare them in certain respects (e.g., symmetrical vs. asymmetrical) to see if these qualities are associated with greater or less discriminability. The "perceptibility" of forms in relation to such contour characteristics as symmetry, continuity, etc. has been studied by Fitts, Weinstein, Rapaport, Anderson, and Leonard (1956) and recently by Klemmer (1961). Undoubtedly, the role played (if any) by a dimension such as symmetry in "pattern difficulty" (to use Klemmer's term) would vary with the judgment required and with the set of other items also being judged. Under the conditions of the present experiment, symmetry did have a significant effect. Symmetrical standards were confused with their variants less often than asymmetrical ones were confused with theirs. The difference appeared in all five age groups ($p < .02$ in every case and $< .001$ in three cases), but the magnitude of the difference was very small. This finding agrees with the two studies mentioned.

Klemmer investigated, also, the effect of continuity and of a closed loop. All our standards were continuous, but since half the standards possessed a closed loop and half did not, they were compared for the latter characteristic. Here the results disagreed with Klemmer's; more errors were made when the standard possessed a closed loop. The difference was not significant at every age level, although it was in the same direction.

The straight-curved classification in our experiment was a three-way one, for four standards were all straight, four all curved, and four mixed. When these three types were compared, the all-curved standards were associated, at all age levels, with more errors than all straight. But the mixed figures occupied an ambiguous position with respect to them.

These "absolute" characteristics of a standard seem to us trivial as predictors of identifiability when compared with the transformations within the set to be judged. In other words, the influence of similarity within a set (here the transformations in relation to the standard) seems to us more important than any characteristic of the standard as such.

DISCUSSION

The most obvious and hardly unexpected outcome of the experiment was that the visual discrimination of letter-like forms, using a matching procedure which requires a judgment of same or different, improves from age four to eight. What are the reasons for improvement? Better ability to keep the task in mind and follow it through cannot be wholly ruled out, but preliminary practice, instruction, and assistance in scanning when required rendered this factor minimal. Maturation of retinal processes is still continuing during this period, but acuity as such should have been adequate even for the 4-yr.-olds. It seems, rather, that children between four and eight learn something about letter-like forms which makes possible better discrimination even between ones they have not seen before.

Our results suggest that what they learn are the features or dimensions of difference which are critical for differentiating letters. Some are critical, but some are not, and the latter variations in letters must in fact be tolerated. Here it is useful to consider Roman Jakobson's concept of "distinctive features" of phonemes (Jakobson & Halle, 1956). Phonemes, like graphemes, must be differentiated from one another, but many variations are permissable without destroying identifiability; the same phoneme pattern is recognizable when it is delivered by a high-pitched or low-pitched voice, whispered, shouted, sung, and so on. Brown (1958) has referred to this as "constancy of the phoneme." But certain features—the "distinctive" ones—are invariant and must be heard as such. It is our hypothesis that it is the distinctive features of grapheme patterns which are responded to in discrimination of letter-like forms. The improvement in such discrimination from four to eight is the result of learning to detect these invariants and of becoming more sensitive to them.

The 4-yr.-olds do, of course, discriminate the letter-like forms up to a point. They have had some experience with alphabet blocks and picture books. But, more important, some of their previous experience with solid objects could transfer to this new discrimination task. Solid objects also have invariant qualities and distinctive features, and a 4-yr.-old has learned what he needs to distinguish many of these, perhaps at the same time he began to distinguish the invariants which permit constancy of shape and size as he moves about in space. The question is, Why should the four types of transformation differ in difficulty at the outset and why do errors decrease at different rates?

The perspective transformations produced the greatest number of confusions in the 4-yr.-olds. Was this because the amount of physical change was small? We have no absolute measure for comparing degrees of change. Nevertheless a 45° slant is very appreciable; acuity is good for it with judgments of moving perspective transformations (Gibson & Gibson, 1957) in adult *S*s. But there was no motion in the present experiment- i.e., no indication of a depth difference. Furthermore, perspective transformations are not distinctive features for object identification. On the contrary, these variations must be tolerated for shape constancy to occur. Therefore, no transfer from discriminating solid objects of the world can be expected for this dimension, since the compression-like changes which result have never been critical for judging objects as same or different. Consequently, errors occurred at a very high rate when *S* was asked to match letter-like forms differing only by this type of transformation.

The decrease in these errors with age was also very slight because perspective transformations are no more distinctive features of letters than of objects. More or less compression must be tolerated in reading the same letter when the page is held at various angles to the line of sight.

At the other extreme are topological transformations—changes produced by breaking or closing a line. Differences of this type are not continuous, and they are critical for object discrimination. Piaget and Inhelder (1956) showed that children discriminate them with solid objects at a very early age. The difference is perceived as well in line drawings. The error curve for breaks and closes of lines began low initially and dropped, reaching zero at 8 yr., because this feature is critical for distinguishing letters as well as objects (i.e., the difference between C and O).

Initial errors for reversals and rotations would also be expected to be high because transformations of this type are not critical for identification of objects as same or different. Rotation gives information about the position of an object. If habits formed for object-discrimination are used when the child begins to make graphic discriminations, confusions due to rotation are to be expected, and in fact occurred. A right-left reversal (mirror reversal) is equivalent to turning over a flat object from front to back and again is not significant, usually, for distinguishing solid objects. Although this curve started high, it fell rapidly to near zero at 8 yr., for the child learns during this period that transformations of rotation and reversal *are* significant for distinguishing graphic forms (i.e., the difference between M and W, C and U, d and b, p and b).

The error curves for line-to-curve transformations need a more complex interpretation. For solid forms, the equivalent transformation would be a deformation of a rigid object, and in that case a critical one. But for living things or plastic objects, elastic transformations of line to curve do occur (i.e., changes of facial expression) and are not significant for identifying an object as same or different; they indicate, rather, a change of state. Transfer to graphic discriminations is therefore equivocal. The amount of the change (one to three changes) was important here. With three changes the error curve was initially low, but with one it was high. The prediction for eventual discrimination, however, is clear. These changes are critical ones for graphemes (i.e., the difference between U and V), and the error curve, at eight, has dropped almost to zero.

The developmental error curves for the four types of transformation that were studied can, then, be interpreted successfully and convincingly by the hypothesis that the child has to learn the distinctive features of letters and that he does not start "cold" because of transfer from his already good ability to differentiate critical features of objects. It may occur to the reader that we have not dealt with all the features by which one letter differs from another. This is of course the case; the set of distinctive features of letters is greater than the set of variables chosen here. Also, the set of noncritical variations of a letter was not fully explored (size, for instance). An attempt is at present being made to work out a fuller set of distinctive features for graphemes. When the set is available, predictions can be made and tested with a confusion matrix.

Another question of interest is how the distinctive features are detected by the child. Teachers apparently give a good deal of concentrated and highly verbal attention to reversal and rotation errors. But there is no evidence that teaching is required. It may be that the child learns which varying dimensions of letters are significant and which are not by simply looking repeatedly at many samples containing both varying and invariant features. The distinctive features of phonemes are not taught but they are nevertheless learned.

Helping the child to pay attention to the distinctive features can hardly hurt, however. If we knew the set of such features, they could be incorporated in some of the "reading readiness" tasks which involve visual discriminations. There is little or no evidence that these experiences transfer to reading. But if the typical matching tasks used variables which are significant for letter discrimination (instead of pictures of objects), there would certainly be greater potential transfer value.

Summary and Conclusions

This experiment studied qualitatively as well as quantitatively the development of visual discrimination of letter-like forms in children four through eight. The forms were constructed according to the same constraints which govern formation of printed capitals. Twelve were chosen as standards, and 12 specified transformations were constructed for each standard. The transformations were three degrees of change from line to curve or vice versa; five changes in orientation; two perspective transformations; and two topological transformations. The discrimination task required *S* to match a standard form with an identical form. All *S*s matched for all 12 standards. Errors were classified according to type of transformation erroneously identified with the standard. The experiment was repeated for the 5-yr.-old group using real letters.

Overall error scores decreased with age, but difficulty of discrimination was different for different transformations. Initial errors were greatest for perspective transformations and least for topological transformations, with changes of rotation and reversal in between.

Changes of line to curve varied in difficulty depending on the number of changes.

The slopes of the curves differed, as well as the initial error. The four classes of transformation showed similarity of slope within the class, but significant differences between them.

Errors made with real letters correlated significantly with errors made with letter-like forms. The correlation between mean errors for different transformations in the two sets of material was +.87, showing that the kind of transformation defining similarity or difference between two forms is a good predictor of confusion errors.

The differences between the developmental error curves for the four types of transformation were interpreted in terms of a hypothesis of distinctive features. Features which have been in the past critical for distinguishing objects are assumed to transfer to graphic discriminations. Discrimination learning continues from this point for distinctive features of letters, but proceeds slowly, if at all, for those varying features of graphemes which are not critical for distinguishing them.

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