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The purpose of this Title VI study was to determine which pairs of lowercase alphabet letters were most frequently confused by prereading children and therefore most likely to cause difficulty in initial reading. Two sample groups were used: 50 lower-middle-class kindergarten children with a median age of 6 years and 25 upper-middle-class nursery school children with a median age of 4 years 4 months. The subjects were required to match a stimulus letter with one of two choice stimuli. A one-way analysis of variance was used for error scores. The most frequent confusions were reversal and rotation transformations. While the types of letter errors have remained approximately the same for over 40 years, the frequency of errors appears to have drastically reduced. Previous research is discussed. Tables, diagrams, and references are included. (Author/RT)

VISUAL DISCRIMINATION: LOWER CASE LETTER CONFUSION[1]

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The purpose of the present study was to determine which pairs of lower-case alphabet letters were most frequently confused by prereading children and therefore most likely to cause difficulty in initial reading. Ss were required to match a stimulus letter with one of 2 choice stimuli. The most frequent confusions were reversal and rotation transformations. While the types of letter errors have remained approximately the same for over 40 years, the frequency of errors appear to have drastically reduced. Previous research is discussed.

One of the most basic features of a reading program is the ability to discriminate the letters of the alphabet. While a large body of literature has developed about which of these letters are most confusing to young children, most of the research has dealt with specific types of errors for single letters, e.g., rotations or reversals. Unfortunately, there is very little research evidence on the actual letter pairs frequently confused.

Davidson (1935), Hill (1935) and Smith (1928) were concerned with the visual discrimination of single letters. Davidson (1935) investigated the extent to which kindergarten and first grade children confused specific letters (b, d, p, and q) and was primarily interested in the reversal type of error. Hill (1935) was mainly concerned with specific categories of disorientation: "horizontal disorientations" (b and d), "vertical disorientations" (b with p), and "diagonal disorientations" (d with p). Although Smith (1928) investigated the ability of first grade children to match all of the lower-case letters of the alphabet, no information was provided as to the confusability of letter pairs.

Popp (1964) provided some insight into the visual discrimination of prereading children as to the confusability of letter pairs as well as individual letters. Popp's analysis of confusing letter pairs was based on the consideration of the "distinctive features hypothesis." Gibson, Gibson, Pick and Osser (1962) hypothesize that "it is the distinctive features of grapheme patterns which are responded to in the discrimination of letter-like forms...and...the

improvement in such discrimination is the result of learning to detect the invariants and becoming more sensitive to them [p. 904]." They noted that topological transformation (e.g., c with o), rotation and reversal transformations (b with d; p with q) and line to curve transformations are critical for letter discrimination with the two latter transformations decreasing significantly with age and the former having the lowest percentage across ages.

The purpose of the present study was to determine which pairs of lower case alphabet letters were most frequently confused by prereading children and were therefore most likely to cause difficulty in initial reading instruction. The identification of confusing letters and letter pairs makes the teacher cognizant of the relative difficulty of the various letters and consequently allows her to distribute her practice accordingly. The method used was essentially the same as the one Popp (1964) used in her study of the visual discrimination of lower-case letters.

Method

Subjects. Two samples of children were used. One sample consisted of 50 children, with ages from five years five months to six years four months (median age six years zero months), who attended a public kindergarten in a lower-middle-class community. The population of children in this school district rank at the national average on intelligence and achievement tests. The second sample consisted of 25 children, with ages from three years seven months to five years six months (median age four years four months), who attended a public nursery school supported by a leading university in an upper-middle-class community. The children of this school district rank well above the national average on national school evaluative tests. Each sample of children was divided into five groups, numbered 1 through 5. The kindergarten sample had ten Ss in each group and the nursery sample had five Ss in each group, with an even distribution of chronological ages within the groups. Testing was done in April before the children had received any formal prereading instruction.

Criterion for S's selection was based on a test which required seven consecutive correct responses on a matching task using only the letters X and O. One child in each sample failed to reach within 15 cards and was replaced by another child of the same age.

Materials. A set of 3 x 5 cards was used. A sample stimulus of a capital letter appeared in the upper center section of each card, with two alternative choice stimuli displayed just below and to the right and left of the sample. One of the alternative choice stimuli was identical with the sample stimulus. For a correct choice the S had to match the sample stimulus with the identical one in the alternative choice set. All three of the lower-case letters were in large primary print, 1/4 in. in height.

There were 25 capital letters for each of the 26 sample stimuli, to give a total of 650 cards. A Gellerman Series (Gellerman, 1933) was used to determine whether the correct letter in the alternative choice set was placed at the right or left of the sample. The Gellerman Series was also used to determine the sequence in which the cards were displayed to the S. A constraint of no more than two successive cards with the same sample stimulus was imposed.

Procedure

The 650 cards were divided into five sets of 130 cards. Groups 1 through 5 within each sample received a different set of cards, but identically numbered groups in the two samples received the same set of cards. For the kindergarten sample 650 cards were discriminated ten times and the 325 letter pairs were discriminated 20 times. For the nursery sample 650 cards were discriminated five times and the 325 letter pairs were discriminated ten times. Each S responded to a card by pointing to the alternative choice stimuli that matched the sample stimulus. When the S made the error, the E flipped the card over and continued on to the next card. The errors were tallied by the E after the S had left the testing room. The E and S sat at a small table facing each other. Testing time per S was approximately ten min.

To check on the experimental control and to provide a chance distribution of errors, 13 X-O items were placed randomly in the 130 cards presented to each S (making a total of 143 discriminations per child).

Results

A one-way analysis of variance was used for error scores. The variance tables for differences in error scores between the five groups of each sample are presented in Tables 1 and 2. The F-value for each sample was not significant at the .05 level, indicating that the differences between groups of each sample can be ignored.

Insert Table 1 and 2 about here

The F-value for the differences in error scores between the five groups across the two samples was not significant at the .05 level (see Table 3), indicating that the differences between groups across sample can also be ignored.

Insert Table 3 about here

As Table 4 indicates, there is a significant difference ($p < .01$) in the error scores between samples indicating that the kindergarten children had significantly fewer errors than nursery children.

Insert Table 4 about here

Further analyses indicated, however, that there was no difference in error scores: (1) between sexes across samples; (2) between sexes in the kindergarten sample; (3) between sexes in the nursery sample; (4) between males across samples or; (5) between females across samples, although the two latter analyses approached statistical significance at the .05 level ($F_{1,33} = 3.40$ and $F_{1,33} = 3.98$, respectively).

Table 5 indicates the number of errors made on each letter pair for each sample. The total number of letter pair errors for both samples are presented in Table 6.

Insert Tables 5 and 6 about here

Figure 1 shows a frequency distribution of errors per letter pair for both samples. Comparing this distribution with the distribution of errors for letter pairs which the children were known to be able to discriminate (see Figure 2) provides the probability that errors are due not to chance, but to discrimination ability. The latter distribution was constructed from the error scores on the 65 X and O cards or 32 pairs (one was discarded). One or more errors were significant for the kindergarten children (at the .03 level) while two or more errors were significant (at the .06 level) for the nursery children. (To facilitate readability, only those "confusions" of two or more errors are underlined in Tables 5 and 6.)

Insert Figures 1 and 2 about here

For the kindergarten and nursery samples the Ss' error rate on the X-O cards were 0.15 and 0.31 per cent, respectively; the Ss' error rate on the letter cards for the kindergarten and nursery sample 1.06 and 1.35 per cent respectively. This suggests that the discriminatory task was not too difficult for these children. Collapsing the two samples, the range of errors per S was from 0 to 18 on the 130 items.

A comparison of lower-case letter pairs significantly confused in the present study and the Popp study (1964) is presented in Table 7. A list of the relative difficulty of each individual letter is shown in Table 8. The differences in error percentages between the three studies may be due in part to differences in Ss, method, or types of alphabet letters.

Insert Tables 7 and 8 about here

Discussion

The present study was designed to measure the "confusability" of lower-case letters of prereading children as a means of determining the relative difficulty in discriminating such pairs. The samples of nursery and kindergarten children appear to differ (in favor of the kindergarten children) in their discriminatory ability of lower-case letters. Previous research by the present authors (Blair & Ryckman, 1968), however, indicated no difference between these same samples of children in discriminating upper-case letters. These results may be due to a difference of graphemic properties. It is interesting to note that the error rate and type of error of Popp's (1964) sample of kindergarten children is more similar to our sample of nursery school children than to our kindergarten sample.

Combining the nursery and kindergarten children, the error rate for discriminations was 3% (N = 75) whereas Popp (1964) found 14% (N = 65). One explanation for this discrepancy in error rate might be the differences in apparatus. Popp used a discrimination apparatus developed by Hively (1962). The child responded by pressing the window of a projector display panel containing the stimulus he has chosen as matching the sample stimulus. A correct response

was necessary before the projector advanced to the next sample stimulus. Responding to an incorrect stimulus necessitated the child pressing the correct or alternative stimuli before the projector advanced to the next stimulus. As a result, an inflation of errors may have been recorded. The present authors found that approximately one-third of the children pointed first to the sample stimulus, then the incorrect choice stimuli, and then the correct choice stimuli. Of these children this response occurred from 1% to 100% of the time. When asked to discriminate the card again, the correct choice stimuli was pointed to immediately in every case. Thus, the children in the present study had a much lower mean error rate than did Popp's sample.

Whereas the error rate for discriminations varied between the present study and the Popp study, the types of errors were primarily the same and help substantiate the analysis by Gibson, Gibson, Pick and Osser (1962). Combining the two samples, most of the error pairs were reversal and rotation transformations. In addition, the kindergarten children made fewer line-to-curve transformations and break-and-closed transformations than did the nursery children, which Gibson et al. (1962) suggest drop with age.

While children for over 40 years have had discrimination problems with the same letters, the frequency of errors per letter appears to have drastically reduced. Whereas Smith (1928) found 11 letters with an error rate above 10%, Popp (1964) found no error rate above 10%, with over 4% for all letters. The present authors, however, found no letter error rate above 2.5%.

Footnote

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Table 1

Analysis of Variance of Error Scores for Kindergarten Children

Source of Variance	SS	df	MS	F
Between groups	12.88	4	3.22	0.47
Within groups	306.90	45	6.82	----

Table 2

Analysis of Variance of Error Scores for Nursery Children

Source of Variance	SS	df	MS	F
Between groups	19.04	4	4.76	0.24
Within groups	401.20	20	20.06	----

Table 3

Analysis of Variance of Error Scores Between Groups Across the Two Samples of Children

Source of Variance	SS	df	MS	F
Between groups across waves	11.42	4	2.86	0.25
Within groups across waves	804.93	70	11.50	----

Table 4

Analysis of Variance Between Kindergarten and Nursery Children

Source of Variance	SS	df	MS	F
Between waves	76.33	1	76.33	7.53*
Within waves	740.02	73	10.14	-----

* ($p < .01$)

Table 5

Total number of errors for kindergarten children		Number of Errors Made on Each Letter Pair																										Total number of errors for kindergarten children
		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	
4	a		1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
9	b	1		1	4	1	1	0	2	0	1	0	0	0	1	0	0	4	0	0	0	0	0	0	0	0	0	16
4	c	1	0		0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	4
11	d	0	4	1		1	0	0	2	1	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	1	0	14
4	e	1	1	0	0		0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	5
6	f	0	0	0	0	0		0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	5
5	g	0	1	0	0	1	0		0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	3
7	h	1	0	0	0	0	0	1		1	0	1	0	0	1	0	0	1	1	0	0	3	0	0	0	0	0	13
8	i	0	0	1	1	0	2	0	0		2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	8
3	j	0	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0	1	0	2	0	0	1	0	0	3	11
2	k	0	0	0	0	0	1	0	0	0	0		0	0	0	0	1	0	0	0	0	1	2	0	1	0	0	7
2	l	0	0	0	0	0	0	0	0	2	0	0		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
4	m	0	0	0	0	0	0	1	0	0	0	0	0		1	0	0	0	0	0	1	0	0	0	0	0	0	3
11	n	0	0	1	0	1	1	0	2	0	0	0	0	1		0	1	0	1	0	0	2	0	0	0	1	0	8
1	o	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	0	0	0	0	0	0	0	0	0	0	4
4	p	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0		4	1	0	0	0	0	0	1	0	0	9
9	q	0	1	0	2	0	1	0	0	0	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0	0	13
3	r	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	1	0	0	0	1	0	7
3	s	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0		0	0	0	1	0	0	0	2
9	t	0	0	0	0	0	0	0	0	1	3	1	0	0	0	0	0	1	1	0		0	0	0	0	1	0	6
6	u	0	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0		1	0	0	0	0	8
7	v	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0		0	0	0	0	4
1	w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		1	1	0	4
3	x	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0		1	0	7
6	y	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	3	0	0		0	8
6	z	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0		3

Table 6

Number of Errors Made on Each Letter Pair for All Children

Total number of errors		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	
7	a	2	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	a
25	b	1	8	2	1	1	2	0	1	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	1	b
8	c	1	0	0	0	0	1	0	0	0	0	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	c
25	d	1	0	0	2	2	0	0	0	0	0	0	0	3	6	0	0	0	0	0	0	0	0	1	1	0		d
9	e	0	1	1	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0		e
11	f	0	0	3	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	f
8	g	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0		g
20	h	1	0	1	0	0	3	0	0	1	0	1	0	0	1	1	0	0	6	0	0	0	0	0	0	0		h
16	i	2	0	2	1	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	1	1				i
14	j	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	5	0	0	1	0	0	3				j
9	k	0	0	0	0	1	0	0	0	1	1	1	2	0	1	0	0	0	0	1	0	0						k
3	l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0					l
7	m	2	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0					m
19	n	0	1	0	1	1	0	4	1	0	0	1	1	0	0	0	0	0	0	0	0	0						n
5	o	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							o
13	p	6	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0								p
22	q	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0									q
10	r	0	1	1	0	0	1	2	0																			r
5	s	0	0	0	1	0	0	0																				s
15	t	0	0	0	0	2	1																					t
14	u	1	1	0	0	0																						u
11	v	0	1	3	1																							v
5	w	1	1	0																								w
10	x	1	0																									x
14	y	0																										y
9	z																											z

Table 7

Letter Pairs Significantly Confused

Present Study						Popp (1964) Data	
Kindergarten Ss		Nursery Ss		Total Ss*			
b-d	4	b-d		b-d	8	p-q	10
h-u		b-q	4	p-q		b-d	9
j-t	3	d-q		d-q	6	b-q	7
v-y		p-q		h-u		d-p	
p-q		h-u	3	b-q	5	b-p	
d-q		j-z		j-t		h-u	
d-p		b-h		n-u	4	i-l	6
n-u	2	d-h		d-p		k-y	
h-n		o-c		h-n		t-u	
i-f		o-e	2	j-z	3	c-e	
i-l		j-t		v-y		d-h	
		n-u		i-f		h-n	5
		k-v				h-y	
		i-j				j-k	
						n-u	

* Letter pairs having an error frequency of 2 for the total Ss would be the same as the total of the kindergarten and nursery Ss' letter pair errors.

Table 8

Graphemes with the Highest Percentage of Errors

Present Study				Popp (1964) Data		Smith (1928) Data	
Kindergarten Ss		Nursery Ss					
d	01.69	b	02.46	u	10.00	b	34.1
n	01.69	d	02.46	q	09.69	p	28.1
t	01.38	q	02.15	d	08.92	q	22.5
q	01.38	h	02.00	h	08.77	d	21.6
b	01.38	j	01.69	p	08.77	r	14.1
i	01.23	p	01.38	v	08.00	h	13.3
v	01.08	y	01.23	b	07.85	f	13.3
h	01.08	u	01.23	e	07.69	i	12.5
f	00.92	n	01.23	f	07.54	j	12.5
u	00.92	i	01.08	i	07.54	n	12.5
y	00.92	k	01.08	k	07.54	u	10.8
z	00.92	r	01.08	t	07.23		
		x	01.08	r	06.78		
		t	00.92				

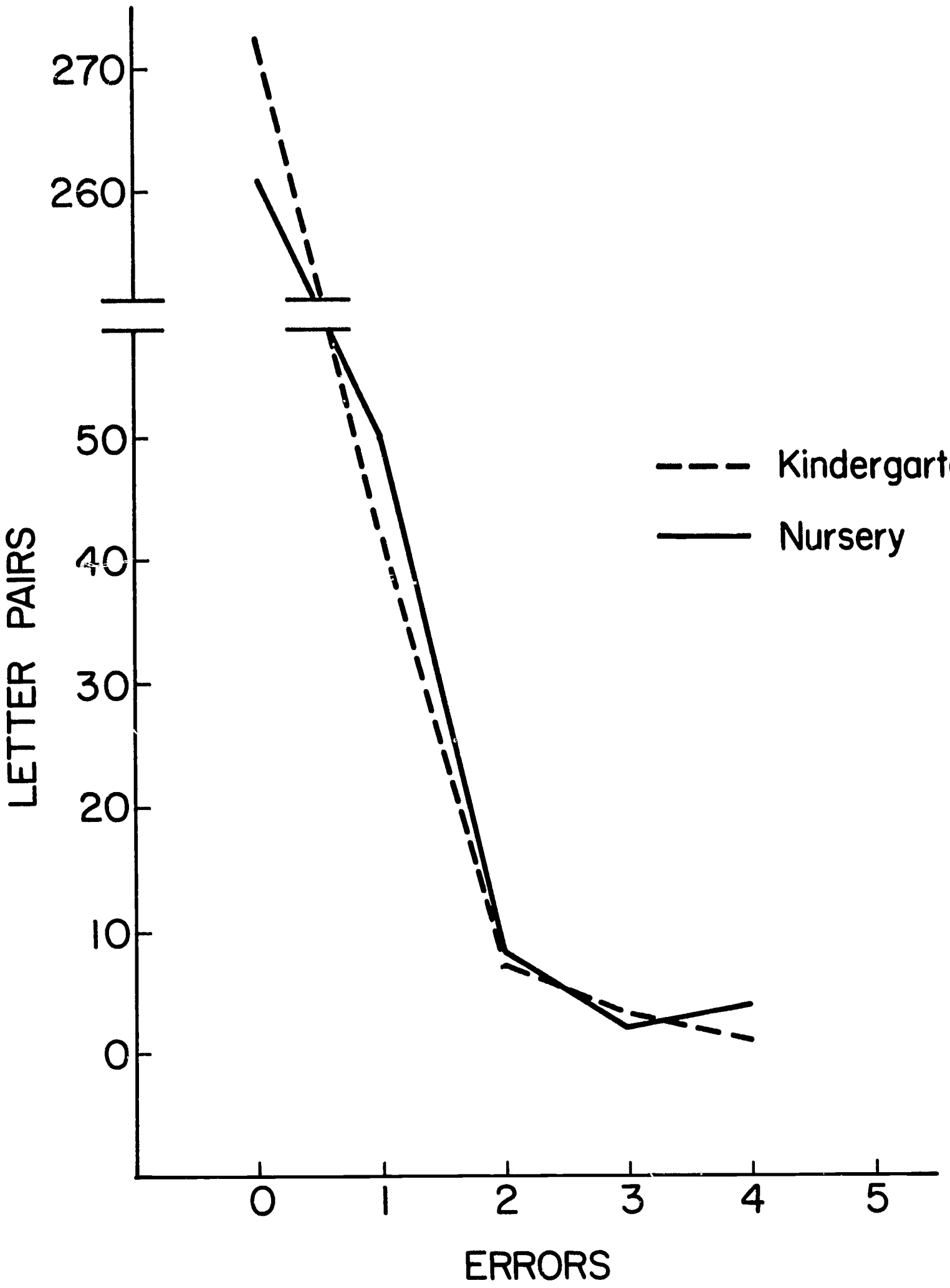
270
260
50
40
30
20
10
0
LETTER PAIRS
0
1
2
3
4
5
ERRORS
Kindergarten
Nursery

Figure 1

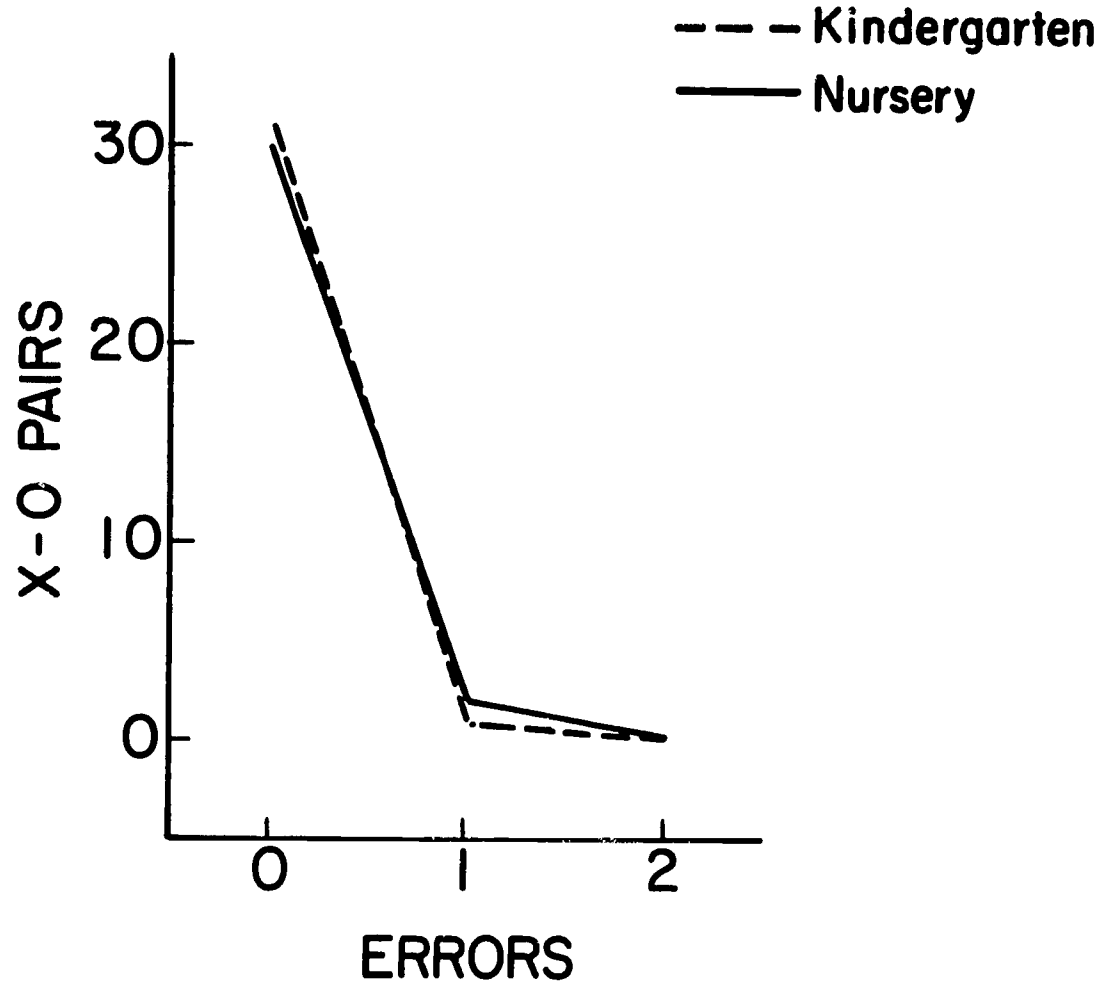

Figure 2