A PROPOSED MODIFICATION OF THE KING-DEVICK SACCADE TEST AND ITS CORRELATION TO READING LEVEL IN A SECOND GRADE POPULATION

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OPT 699: Special Studies

ABSTRACT

In light of the intimate relationship between saccadic eye movements and reading, measurements of saccadic fixation ability are often utilized as indicators of poor reading ability. The Pierce Saccade Test is a standardized test which has been used in the past for this purpose. This test has some shortcomings, in that the saccades involved are widely separated and equally spaced, resulting in contamination due to habituation and anticipation. Further, the amplitudes and line width of the required saccades are far greater than those habitually encountered in normal reading tasks. The King-Devick modification of the Pierce Test added more fixations to each line, thus reducing the amplitudes of the required fixations, and subsequently found that their test better differentiated between good and poor readers than did the Pierce Test. However, the King-Devick Test still utilizes a greater line width, and somewhat larger saccadic amplitudes than are commonly encountered in normal reading.

In an effort to simulate the magnitude of saccades and line widths most commonly used in everyday reading material, a new saccade test was devised, based on the modification of King-Devick Test III. This test, along with K-D III (King-Devick III), was run on 33 second grade students in the Big Rapids area, whose age ranges were seven years and four months to nine years and one month. Each of the students were classified as either adequate or inadequate readers by the estimation of their classroom teacher, with whom they had worked for approximately seven months. Mean values and standard deviations were determined for each of the groups, and

correlations between reading abilities and test scores were determined for each of the tests administered.

The results indicated a good correlation between the KD-III and the modification thereof, when applied to good readers, but a poor correlation between the two tests when used on poor readers. The study showed the difference in the means for good and poor readers to be significant to the .001 level for the KD-III Test; however, the difference in the means for the modified saccade test were not found to be significant at the .05 level necessary for clinical use. There was also a significant difference in the means for the two tests, indicating that the format for presentation of the figures is a very important factor in both the time required for completion of the task, and for the ability of the test to differentiate between good and poor readers. The significant difference in means between the two groups with the KD-III indicates this test is much better for differentiating between good and poor readers than is the modification of the test used here.

SACCADES AND READING

Eye movements associated with reading have been subject to study for many years. Originally thought to be smooth and pursuit-like in nature, Professor Emile Javal, in 1978, discovered by simple observation that eye movements during reading were a series of small jumps with intervening fixation pauses,[17] and thus the term saccade was initially defined to be "rapid movements between fixation focuses that occur in reading.[5]

Following the realization that eye movements were not smooth and sweeping in nature, it became necessary to determine if visual information is taken in during saccadic movements. Ludlam[13] provides a brief literature summary of evidence to indicate a cortical suppression during saccadic movements, while Richards[14] proposes a retinal suppression due to a shearing effect during movement. In any case, the important factor for this discussion is the agreement that some type of suppression does occur, indicating that all information acquired from reading must be taken in during the brief fixation pauses of approximately 250 msec. duration[3] found in the average reading task. Thus, it is apparent that the accuracy and speed of saccadic eye movements will play an important role in the efficiency of reading.

Measuring Saccadic Movements

Although four eye movement systems (saccadic, pursuit, vergence, and vestibular) interact constantly in normal reading activity,[3] the saccadic system has the greatest bearing, and hence has been given the most

consideration when correlating eye movements to reading deficiencies. The most effective currently available means of measuring eye movements is through infrared oculography, using units such as the EDL Reading Eye Camera®, or the Biometrics Eye Trac®. Several studies using these instruments have demonstrated that poor readers consistently make more fixations, more regressions, and longer fixations than do good readers for any given reading level.[2,3,4,10,11] Unfortunately, the cost and relatively limited use of infrared oculographic units limit their use to educational institutions and those practitioners specializing in pediatric vision care. Clearly, a less expensive alternative for determining saccadic efficiency would be useful to the average practitioner.

John R. Pierce, O.D., of the School of Optometry at the University of Alabama in Birmingham, devised an indirect means of measuring saccadic accuracy, called the Pierce Saccade Test. The test consists of three cards, each with a column of fifteen numbers of approximately 20/70 Snellen size at 40 cm., with the columns separated by 8 3/4 inches (see Appendix I). The subject holds one of the cards before him, and is instructed to read the first number of the left column aloud, then the first number of the right column, the second number of the left column, etc. The time required for completion, as well as the number of errors for each card, are recorded and compared with standardized data for the subject's age and grade level in school. The Pierce Test has several inherent shortcomings: first, the separation of each of the figures by a constant amount introduces two constant errors of habituation and anticipation, as pointed out by King and Devick.[9] Secondly, the separation of 8 3/4 inches between figures results in a saccadic amplitude of

approximately 29 degrees at a 40 cm. working distance, hardly an amount commonly encountered in reading tasks. Leisman and Schwartz[12] indicate that 20 degrees is the maximum angular movement within which the eyes should have to move for maximum reading efficiency. Additionally, a test using such a huge saccadic amplitude virtually eliminates one of the major characteristics of dyslexic saccadic behavior -- regressions. Since regressions are normally of relatively small magnitude,[15] it seems unlikely that many regressions will occur over a 30 degree separation.

In 1976, Alan J. King and Steven Devick, at Illinois College of Optometry, came up with a modification of the Pierce Test, specifically designed to decrease the effects of anticipation and to reduce the amplitudes of the required saccades to a situation more closely related to an actual reading situation. The test is comprised of one demonstration card and three test cards, each containing eight rows of five numbers, each number spaced such that successive saccades are each of a different amplitude than the previous one. The numbers are printed in 11-point type, which corresponds to approximately 20/100 reduced Snellen acuity at forty centimeters. The separation between the left and right margins is reduced from 8 3/4 inches in the Pierce Test to 7 inches for the King-Devick Test. Subsequent testing found the King-Devick Saccade Test to show a chronological age/performance relationship similar to the Pierce Test, with better differentiation between good and poor readers with the K-D as compared to the Pierce.

The King-Devick Test, although decidedly more comparable to a normal reading task, still has some deficiencies in my opinion. First, although obviously much better than Pierce's 29^{o} saccades, the calculated average saccade amplitudes for the K-D tests at 40 centimeters are about 6.4^{o},

with a range of 2.1 to 9.9 degrees, somewhat greater than the 1 to 4 degree normal saccade amplitudes found in normal reading by Ciuffreda, et. al.[3] Griffin, et. al.[6] found that the longer saccadic movements were more easily and acurrately performed, citing Hyde's work which showed that short saccades were considerably more neurologically complex than longer movements[8] as the reason why this is true. Thus, it seems that a test using even smaller saccadic amplitudes may give even more definitive results.

Another discrepancy between both the Pierce and King-Devick Tests and the average reading task is in the length of line used. The line length for the Pierce Test is 52 picas, and a 42 pica line is used in the King-Devick Test. (Note: a pica is a unit of measurement used in the printing industry. One pica corresponds to about 1/6th of an inch.) By comparison, legibility for 10-point type is maximum when a line width of between 14 and 31 picas is used.[16] In addition, consider the following information:

> "(longer line widths)...yielded increases in fixations, pause duration, and regressions (in normal readers). In reading the very long lines, the major difficulty was to locate accurately the beginnings of successive lines following the back sweep from the end of the previously read line. When this difficulty is experienced, it tends to upset the normal reading process so much that re-establishment of the most efficient oculomotor patterns in reading successive lines becomes difficult or impossible." (16)

In light of this information, the potential is there for false positive responses with respect to reading difficulties as judged by performance on either of the aforementioned tests. I feel it may be advantageous to investigate the potential of a test similar to the K-D or Pierce, using a narrower line width and smaller interfixational distances.

Method

In order to evaluate the impact of a different presentation of a test similar to the King-Devick or the Pierce Tests, a modification of the K-D III Test was evaluated and compared to K-D III itself, with regards to either test's efficacy in differentiating between good and poor readers. The format of the author's modification of K-D III may be examined in Appendix III. The author's test uses forty numbers of a 20/100 size, as does King-Devick III Test. The column width for the author's test (herein referred to as the JJM Test) was, however, 3½ inches in width, or 21 picas, as opposed to the 7 inch line width for the King-Devick Test. Also, the numbers in the JJM Test are presented in five lines with eight numbers in each line, rather than eight lines with five letters in each, as in the case of the King-Devick. As in the KD Tests, the JJM Test has its numbers distributed at random intervals within each line, to avoid habituation. The numbers in the JJM Test are separated by a mean distance of 1.26 centimeters, with a range of 0.4 centimeters to 2.7 centimeters. If tested at forty centimeters, the angular extent of the saccades required to fixate each number have a mean value of 1.8 degrees, wtih a range of from 0.6 degrees to 3.9 degrees. Thus, the number, size, and orientation of the stimuli are the same in each of the tests, with the only factor having been altered in the JJM Test being the angular separation and line width of the stimuli. In this manner, evaluation of the two tests on the same populations of good and poor readers will enable us to assess both the efficacy of defining poor readers in a population using KD III, and whether or not the aforementioned modification will improve the test's efficacy.

The JJM Test and KD III were run on a group of 33 second grade students

at Riverview Elementary School in Big Rapids, Michigan, in early April of 1981. All subjects were judged by their teachers to be of normal intelligence. Each of the children were instructed to read each of the numbers aloud, in the order designated by the King-Devick demonstration card, to proceed as rapidly as possible, but to try to make as few errors as possible also. The order in which the tests were presented was switched with each successive subject, so that familiarity with the task was not a factor on either of the tests. The subjects, whose ages ranged from seven years and four months to nine years and one month, were divided into two groups: adequate and inadequate readers for grade level. The groupings were determined by the teachers with whom the children had been working for approximately eight months when the testing had been carried out. It was felt that this means of classification was sufficiently accurate due to the fact that both teachers are well-qualified individuals who had been working with the children for a substantial period of time. The examiner did not know which group the child was in at the time of the testing.

Data

Statistical analysis of the data obtained through the previously described experiment is as follows:

D A T A

KD III				JJM			
Good Reader		Poor Reader		Good Reader		Poor Reader	
X	X^2	X	X^2	X	X^2	X	X^2
29	841	42	1764	27	729	31	961
20	400	50	2500	18	324	27	729
27	729	31	961	26	676	20	400
38	1444	38	1444	28	784	33	1089
34	1156	44	1936	24	576	30	900
37	1369	41	1681	22	484	29	841
24	576	41	1681	23	529	33	1089
28	784	39	1521	20	400	28	784
30	900	40	1600	27	729	21	441
33	1089	31	961	28	784	24	576
27	729	29	841	22	484	33	1089
20	400	42	1764	21	441	21	441
28	784	40	1600	19	361	29	841
28	784			28	784		
41	1681			35	1225		
28	784			25	625		
27	729			20	400		
33	1089			23	529		
38	1444			30	900		
36	1296			30	900		
$\Sigma X=606$ n=20	$\Sigma X^2=19008$	$\Sigma X=508$ n=13	$\Sigma X^2=20254$	$\Sigma X=596$ n=20	$\Sigma X^2=12664$	$\Sigma X=359$ n=13	$\Sigma X^2=10181$

KD III:

Group	n	$\bar{x}$	s.d. (δ)
Overall	33	33.75 sec	7.19 sec
Good Readers	20	30.3	5.78
Poor Readers	13	39.0	5.79

STUDENT'S T-TEST:

$$\Sigma x_1^2 = 19008 - \frac{(606)^2}{20} = 646.2$$

$$\Sigma x_2^2 = 20254 - \frac{(508)^2}{13} = 379.47$$

$$t = \frac{30.3 - 39.1}{\sqrt{\left(\frac{646.2 + 379.47}{31}\right)\left(\frac{1}{20} + \frac{1}{13}\right)}} = -4.24 \text{ (significant at .001 level)}$$

JJM TEST:

Group	n	$\bar{x}$	s.d. (§)
overall	33	25.8 sec	4.61 sec
good readers	20	24.8	4.31
poor readers	13	27.5	4.74

STUDENT'S T-TEST:

$$\Sigma x_1^2 = 12664 - \frac{(496)^2}{20} = 363.2$$

$$\Sigma x_2^2 = 10181 - \frac{(359)^2}{13} = 267.1$$

$$t = \frac{24.8 - 27.5}{\sqrt{\left(\frac{363.2 + 267.1}{31}\right)\left(\frac{1}{20} + \frac{1}{13}\right)}} = -1.72 \text{ (not sig. @ .05 level)}$$

Coefficients of Correlation:

For Good Readers: KD III and JJM, r = 0.70

For Poor Readers: KD III and JJM, r = 0.10

Results

The data shows several interesting results. First, the JJM Test took substantially less time to complete than did the KD-III when administered to the same population under the same testing conditions. A cursory examination of the two tests leaves the impression that the JJM Test should require less time to complete, at least in the mind of the author, and consequently this result is not particularly surprising. A result which is somewhat more surprising, at least with regards to the evidence presented earlier in this paper, is the relative significance in differences between the means for good and poor readers, as determined by the Student t-test. The difference between the means for the KD-III test were found to be significant at the .001 level, a very high level of significance. On the other hand, the difference between the means in the JJM Test were not found to be significant, even at the .05 level necessary to be considered clinically significant. This level indicates that one can be quite confident that a poor reader will not do well on the KD-III, and that the opposite will occur for good readers. The differentiating ability of the JJM Test, however, is not sufficient that it may be used with confidence on a clinical basis. Possible explanations for this result will be discussed later.

Another interesting finding is that a good correlation ($r = 0.7$) was found between good readers on the KD-III and the JJM Tests, but a poor correlation ($r = 0.1$) was found between the two tests with respect to poor readers. From this, one can predict that, if a good reader scores at a certain level with respect to the mean on one of the tests, he can

be expected to score at a similar level with respect to the mean on the other test. The same can not be said for poor readers, however. Poor readers had much greater difficulty with the KD-III, scoring approximately 1.5 standard deviations below the mean for good readers on the same test. By contrast, the same poor readers had a mean time on the JJM which was only 0.6 standard deviations below the mean for good readers.

Discussion

The reduction of width and angular separation of the stimuli of the King-Devick Test, contrary to the evidence presented earlier in this paper, did not improve the test's ability to differentiate between good and poor readers, but rather decreased it substantially. Having presented evidence to indicate why this modification of the test may have been more definitive in the isolation of poor readers, followed by statistical evidence to indicate this was not the case, it now becomes necessary to postulate why the data came out as it did.

One serious problem with any of these "saccade tests" is the requirement of the subject to identify and read the numbers aloud while performing the test. Thus, this type of test is, at best, a test which measures saccadic accuracy indifectly, to, at worst, a number-calling test in which saccadic accuracy is only one of many significant variables. When administered in this fashion, the limiting factor determining the speed with which the task may be performed may not be saccadic accuracy at all; rather, it may be limited by the ability of the subject to recognize and recite the names of the numbers used. The JJM Test has been shown to be completed in considerably less time than KD-III, even

though the number of symbols in the two tests is the same. The response time for each symbol, therefore, is less for the JJM and consequently is probably more susceptable to this type of error than the KD. This may also explain the lack of significant difference in the means of the two groups on the JJM Test -- the JJM may be measuring something more closely related to an oral reading type of task than saccadic function. Thus, a relatively good oral reader with relatively poor saccadic function may perform adequately on the JJM and the converse may be true for a poor oral reader with good saccadic function. Further investigation needs to be carried out to isolate the effects of the number-calling from the saccadic function in these tests before anyone can say with confidence that they are a true indicator of saccadic function.

The very signficant difference in the means (.001 level) found for the KD-III Test in this study tends to reinforce the credibility of this test as a tool for differentiating between good and poor readers. King and Devick went as far as to say that their test identifies poor readers with deficient saccadic abilities -- I don't feel the test results can be carried that far. In their study, the KD Tests were able to isolate students with poor projected reading abilities, as estimated from their I.Q. scores. Their reading deficiencies may be due to any number of factors, saccadic efficiency being only one of them. The significant difference in the means allows one to say with confidence that a good reader will probably do well on the KD Test, and the converse is true for the poor reader. However, when applied in reverse, the statement is not clear-cut. A distinct gray area exists when a given score on the KD is used to try to predict the reading level for a subject, particularly

when the score falls between the means for the two groups. If a score falls more than two standard deviations below the overall mean, one can say with 95% confidence that this score was not due to chance. For scores less than 2 s.d. out, the statement becomes increasingly less accurate. (King and Devick selected their criteria for poor readers to be 1 s.d. or more below the man.)

In summary, this study revealed three significant findings:

1. The presentation and spacing of characters in a test such as the King-Devick or Peirce test has a definite effect upon the speed and accuracy of the performance of the task.

2. The proposed modification of the KD-III Test did not work as well as the original in differentiating between good and poor readers.

3. The King-Devick Test was found to exhibit a very significant difference in the means between tood and poor readers.

I feel the King-Devick saccade test in its present form may still be used as a tool in diagnosing oculomotor deficiencies in poor readers; the examiner should, however, keep in mind the deficiencies of the test, and the fact that it, in itself, is not a pure measure of saccadic function.

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LIST OF APPENDICES

APPENDIX I

THE PIERCE SACCADE TEST

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The Pierce Saccade Test is a short, reliable clinical test for determining saccadic ability between the ages of 6 years and adulthood. It is composed of a demonstration card and three test cards. It can be administered in a few minutes and can be used as a performance test to determine the effectiveness of an ocular motility training program or the immediate effects of lenses and prisms used to aid binocularity.

The demonstration card consists of 10 numbers of approximately 20/70 reduced Snellen equivalent. The letters are separated horizontally by 8 3/4 inches and vertically by 1 5/8 inches. Lines with arrows are drawn to indicate the pattern in which the saccades are to be performed on this test and the following three tests. The patient is instructed to hold the card in the fronto-parallel plane at his normal reading distance. The card should be illuminated by 20 to 60 foot candles of glare free and shadow free illumination. The patient is instructed to call out all the numbers on the card as rapidly and accurately as he can, beginning with the upper left hand number, then the upper right hand number, the second left hand number, the second right hand number, etc. He is not timed on the demonstration card. If the patient moves his head during the saccades on the demonstration card he was instructed to try not to move his head on the following cards.

The three test cards are composed of 30 randomly selected numbers with the same numbers being used on each card but in a different sequence. The lateral separation of the numbers is 8 3/4 inches. The vertical separation is ½ inch on cards one and II and 5/16 inches on card III. Tests I and II differ only in that Test I has a horizontal line to visually guide the patient in making the saccade. Test III differs from Test II in that the vertical separation of the numbers is closer, making it more difficult to maintain one's place during the saccade. The tests have been standardized on the basis of presenting all the tests and in the order: Demonstration Card, Test I, Test II and Test III. These tests are administered in the same manner as the Demonstration Card with the exception that they are timed with a stopwatch and the responses are checked for accuracy.

Instructions: I want you to call out all of the letters on this card as rapidly and as accurately as possible in the manner indicated. Point to the upper left hand number, then the upper right hand number, then the second left hand number, the second right hand number, etc. If the patient proceeds directly down one column, stop him, correct him and repeat the instructions. Ask if the patient understands what he is to do and if he is ready. Then tell him, "ready, start", and begin timing him. Stop the timer when he has completed calling out all of the numbers. Record the time in seconds under the column indicated for Test I.

Recording Errors: Errors are recorded as omission or addition errors, with omission errors being marked with a slash and addition errors marked with a circle. For example:

If Test 1 were:

1	2
3	4
5	6
7	8

and the patient called out: 1, 4, 3, 6, 5, 8, 7, etc., his only error is an omission error having left out the number 2.

If the patient called out 1, 2, 1, 4, 3, 6, 5, 8, 7, etc., he has repeated the number 1 twice and it would be circled as an addition error.

Note that in both of the above examples the patient started making saccades obliquely across the page, oblique saccades should be marked with an arrow indicating the manner in which the numbers were called out, but the patient is only checked for the exact omission or addition error that he made.

If the patient called out 1, 2, 3, 6, 5, 6, 7, 8, the score sheet would be marked as follows and he would be marked for one omission error (4) and one addition error (6)

1	2
3	4
5	6
7	8

Additional observations: It should also be noted by the tester whether or not the patient does any of the following:

Marked head movement: This is defined as a gross head movement in which the head turnes more than halfway across the page when making the saccade.

Slight head movement: A noticeable head movement that is less than one half the distance across the page is noted as a slight head movement.

No head movement is denoted by not checking either one of the above catagories.

Other observations include abnormal working distance, head tilt, frowning, scowling or squinting.

STANDARDIZATION AND NORMATIVE DATA

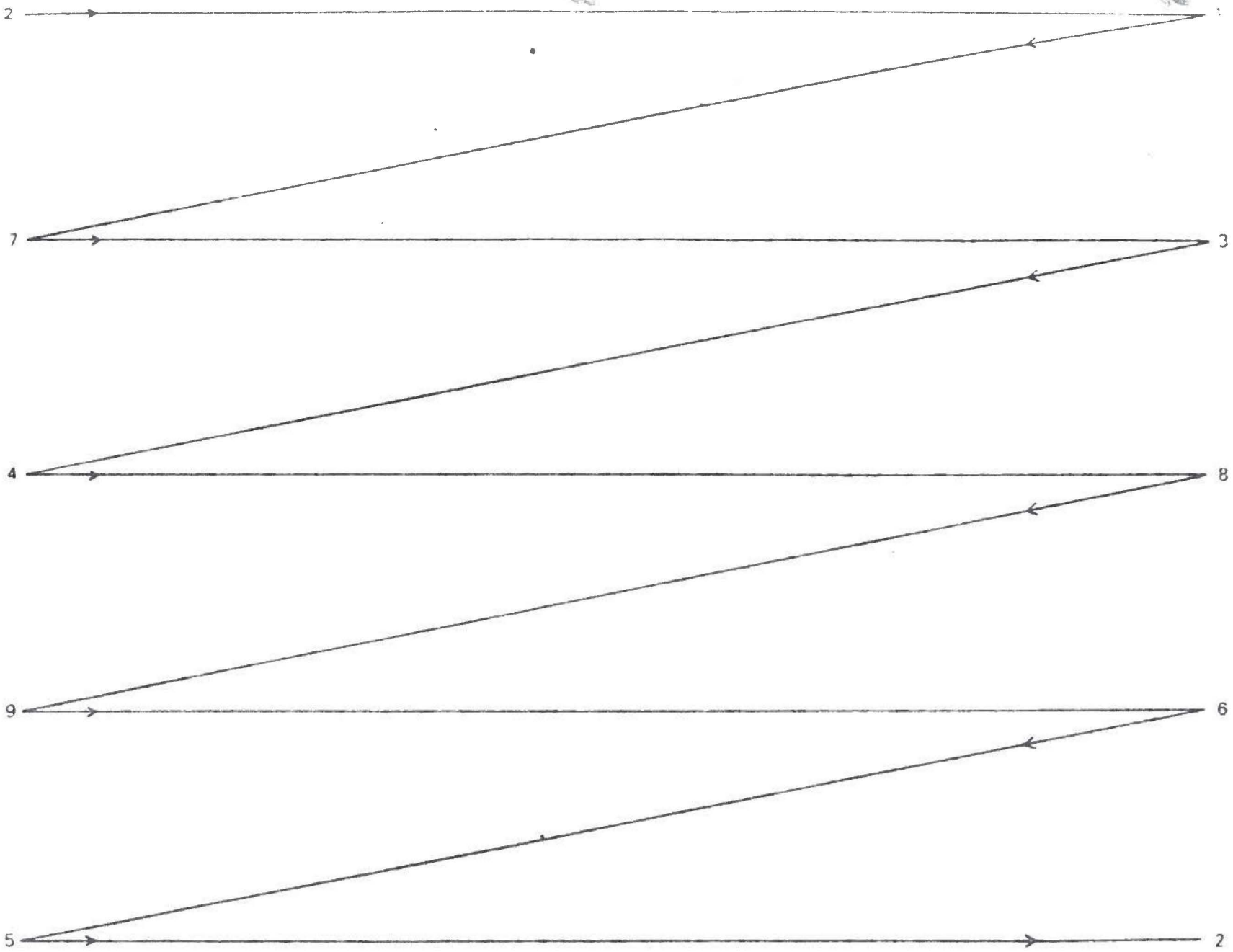
The tests were administered to 288 school-age children in a white, middle class school district in Birmingham, Alabama. All children within normal classrooms were included and no learning disability or retardates were included in the normative study. The tests were administered by the author and by fourth year optometry students from the School of Optometry/The Medical Center, The University of Alabama

in Birmingham. All children tested were capable of performing the test and all data are included. There were no frank strabismics and if the child was wearing spectacles, he was instructed to use them. Acuities were not taken but all children tested were capable of discriminating the test type. Occasionally, a child lost his place or did not follow instructions. They were instructed again as to how to perform the test and then re-run immediately. The second time was recorded as their time for the test.

Children were grouped by one year age groups. The mean age performance on Test I, Test II, Test III and the sum of performance times on I, II, and III were determined as well as the mean for the sum of the addition and omission errors on the three tests. Each measurement was correlated with age and the variance attributable to age alone within each year's age group was removed from the total variance for each age group.

The results of the mean performance times for all children on the three tests is presented in the next graph. Note the curvilinear relationship with age in which the performance at 10 years of age begins to asymptote not far from the performance of the adults. The correlation between age and performance on Test I is .89 and Test II is .91, age and Test III is .87, and age and test I +II +III is .93. This means that 80 percent of the variability on the test can be predicted by age alone. The remaining variance is determined by individual differences, error variance, etc.

Use of the age Vs. performance on Test I+II=III graph. This graph indicates the relation between total performance on all three tests and age. The abscissa represents age and the ordinate total time for all three tests. The performance of any child is determined on each test. The total of his times on test I +II +III is determined and that value found on the ordinate. Dropping straight down from that point, the child's equivalent age is determined. That is, at what age was the average performance of other children the same as his? For example, if a child's total time for tests I +II +III was 93 seconds, his equivalent age or age at which other children performed at this level is 8 years. If he were 12 years old we could say that he is performing at the same level as an 8 year old on this test. Or if he were 6 years old we could say that he was a superior performer, performing at the same level as an 8 year old.



PIERCE SACCADE TEST
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DEMONSTRATION CARD

COOK, INC.
P. O. BOX 498
BLOOMINGTON, IND. 47401

2 — 3

1 — 5

0 — 5

6 — 4

1 — 4

8 — 7

3 — 8

9 — 7

1 — 4

3 — 6

4 — 9

3 — 7

3 — 1

5 — 2

6 — 8

PIERCE SACCADE TEST

COOK, INC.
P.O. BOX 499

5	2
3	1
0	7
4	9
3	6
1	4
9	7
3	8
8	7
1	4
6	4
0	5
1	5
2	3

COOK, INC.

2	8
1	2
0	1
6	7
1	9
8	6
3	4
9	7
1	8
3	7
4	4
0	4
3	5
5	5
6	3

TEST III

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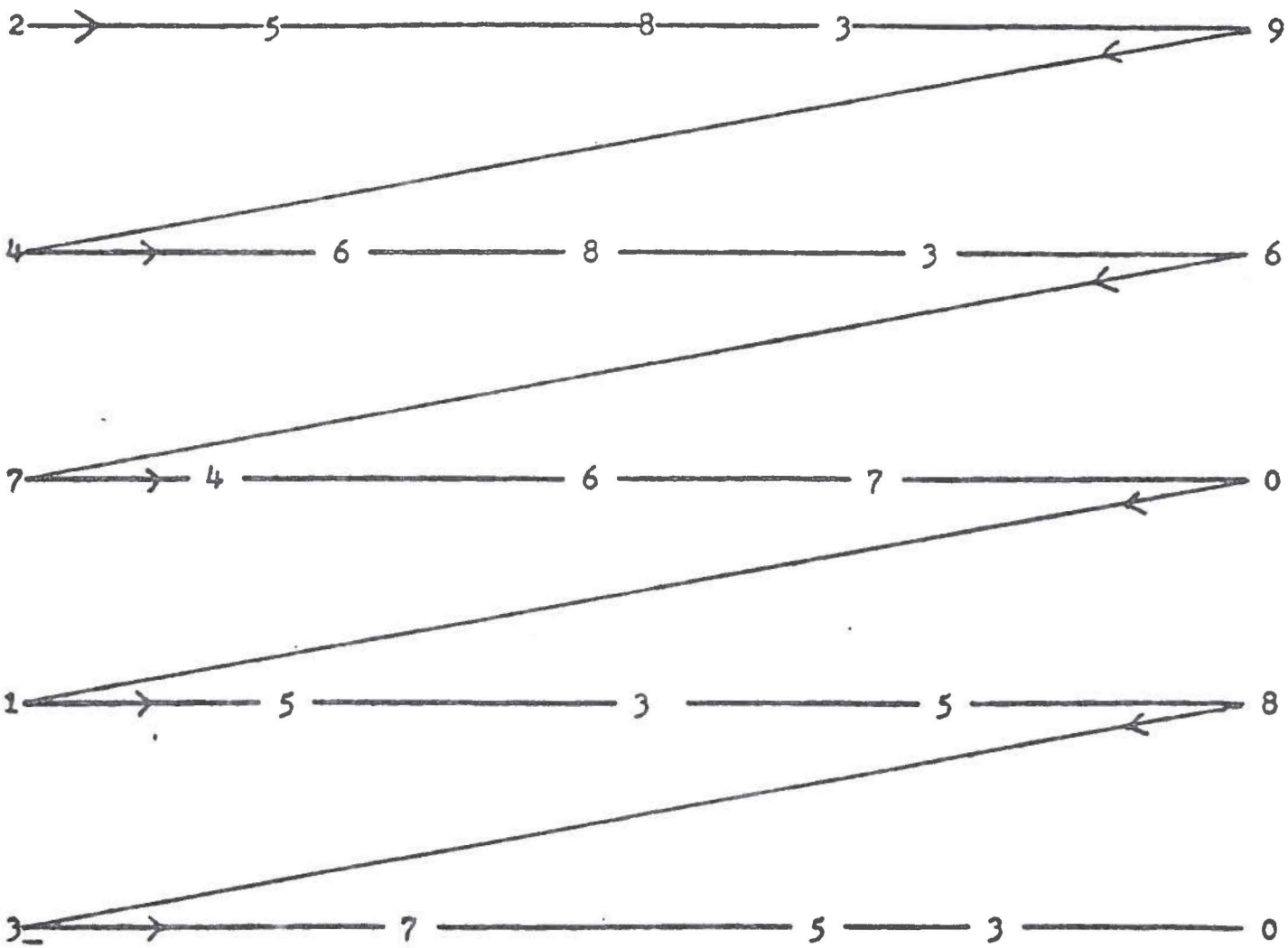
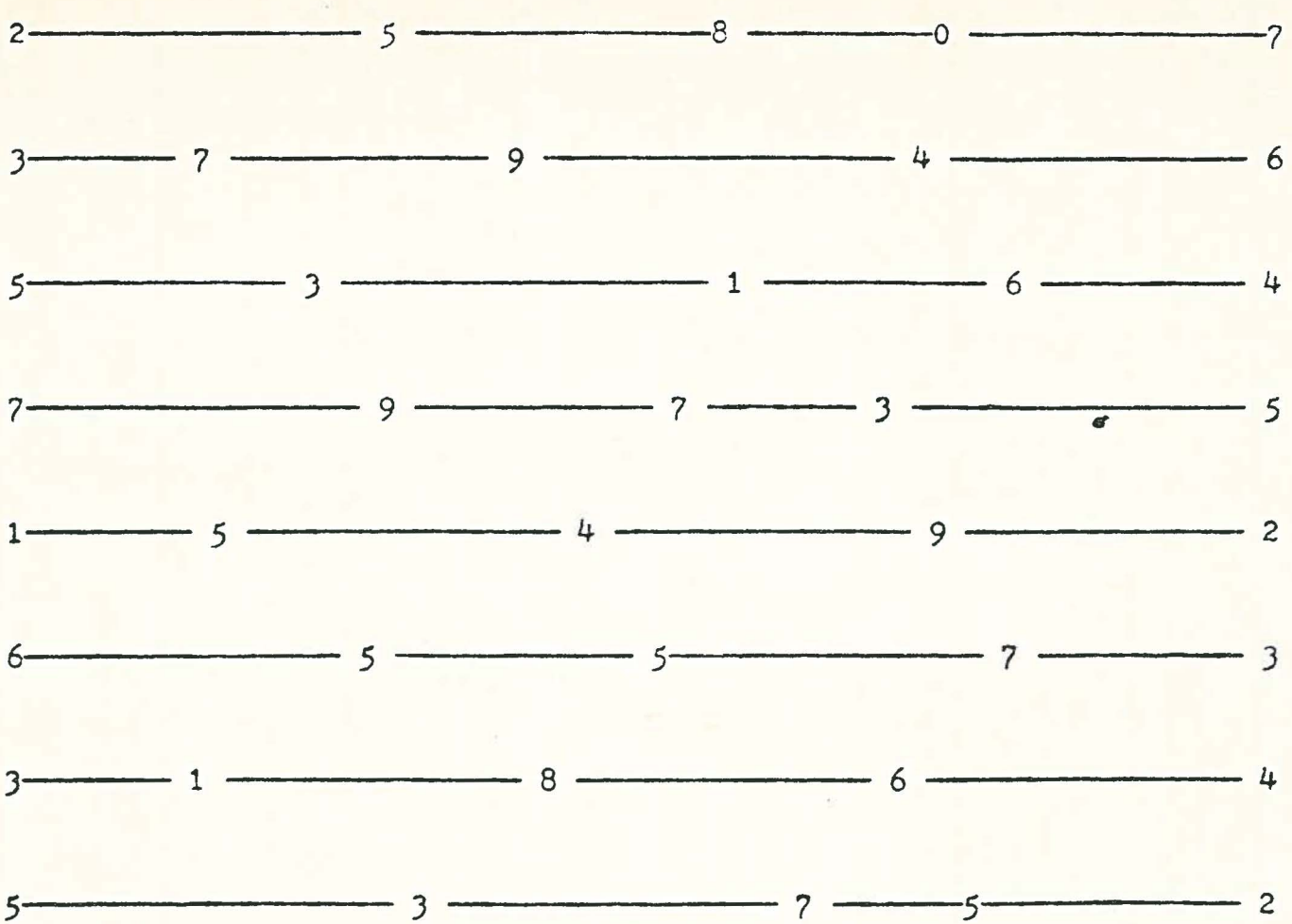
BLOOMINGTON, IND. 47401

APPENDIX II



DEMONSTRATION CARD



TEST I

3 7 5 9 0

2 5 7 4 6

1 4 7 6 3

7 9 3 9 0

4 5 2 1 7

5 3 7 4 8

7 4 6 5 2

9 0 2 3 6

TEST II

5			4		1			8	0
4		6				3		5	9
7			5				4	2	7
3		2			6			9	4
1			4			5		1	3
9				3	4			8	5
5	1					6		3	1
4				3		5	2		7

TEST III

KD Test (sample size 1202)

Age		TIME IN SECONDS				ERRORS			
		I	II	III	Total	I	II	III	Total
6	# of students	100	100	100	100	100	100	100	100
	Average	30 98	37 05	51 00	119 03	1 32	3 61	10 84	16 97
	S.D.	10 10	12 96	10 30	40 92	2 32	5 30	9 30	14 70
7	# of students	127	127	127	127	127	127	127	127
	Average	26 71	31 12	43 00	100 89	1 12	2 10	8 75	11 97
	S.D.	5 07	8 75	15 30	25 16	2 06	4 20	8 01	12 32
8	# of students	223	223	223	223	223	223	223	223
	Average	22 98	24 00	31 26	78 11	34	53	2 48	3 35
	S.D	6 37	7 75	11 50	17 35	1 15	2 16	4 53	6 13
9	# of students	207	207	207	207	207	207	207	207
	Average	21 02	22 89	29 53	73 44	28	45	2 02	2 75
	S.D.	7 20	7 50	10 82	26 01	1 05	1 46	4 31	5 08
10	# of students	117	117	117	117	117	117	117	117
	Average	19 72	20 79	27 76	68 27	28	43	1 12	1 83
	S.D	6 08	7 17	10 21	26 22	1 20	1 18	2 59	3 62
11	# of students	121	121	121	121	121	121	121	121
	Average	17 58	18 95	20 39	56 92	25	37	58	1 20
	S.D	4 80	4 51	7 45	11 85	89	86	1 76	2 50
12	# of students	102	102	102	102	102	102	102	102
	Average	16 94	17 68	19 42	54 04	18	21	44	83
	S.D.	3 60	4 43	5 31	13 51	76	81	1 56	2 26
13	# of students	100	100	100	100	100	100	100	100
	Average	16 20	16 96	18 98	52 23	12	12	36	59
	S.D.	2 52	2 72	3 26	7 50	31	30	1 07	1 26
14	# of students	105	105	105	105	105	105	105	105
	Average	14 86	16 87	18 73	50 46	07	07	33	47
	S.D.	2 40	2 13	2 49	5 84	26	26	1 05	1 13

AVERAGE TIMES AND STANDARD DEVIATIONS

FOR EACH TEST

By Age

	AGE	P-1	P-2	P-3	P-TOTAL	KD-1	KD-2	KD-3	KD-TOTAL
Avg. Time	6	38.20	41.27	39.67	119.20	34.40	39.47	42.07	115.93
Std. Dev.	6	9.17	6.36	8.12	20.96	6.60	10.04	11.54	23.28
Avg. Time	7	38.65	43.71	41.06	121.65	30.18	33.82	39.71	103.71
Std. Dev.	7	7.17	10.17	6.93	18.81	4.72	6.19	7.09	14.46
Avg. Time	8	30.56	33.96	37.12	101.72	24.40	27.92	32.60	84.60
Std. Dev.	8	10.24	8.37	13.20	27.02	5.28	7.07	6.93	17.23
Avg. Time	9	28.13	31.61	31.83	91.57	23.52	23.57	29.43	76.78
Std. Dev.	9	8.43	10.38	8.61	22.31	7.86	6.35	8.68	20.74
Avg. Time	10	25.32	28.11	28.63	82.05	21.26	22.79	25.00	69.08
Std. Dev.	10	7.40	7.74	7.48	20.48	4.78	5.09	7.48	15.57
Avg. Time	11	20.39	24.13	25.09	70.91	20.09	19.87	24.39	64.04
Std. Dev.	11	5.33	4.86	5.32	13.44	4.50	3.45	5.67	12.27
Avg. Time	12	20.47	24.60	26.40	71.33	20.07	21.00	21.73	62.80
Std. Dev.	12	4.91	5.87	6.40	15.78	2.99	4.24	3.77	9.82

AVERAGE TIMES AND STANDARD DEVIATIONS

FOR EACH TEST

By Grade in School

	GRADE IN SCHOOL	P-1	P-2	P-3	P-TOTAL	KD-1	KD-2	KD-3	KD-TOTAL
Avg. Time	1	37.26	40.70	40.26	118.31	32.30	37.30	40.30	110.00
Std. Dev.	1	8.39	6.42	6.76	17.73	6.36	9.16	10.36	21.69
Avg. Time	2	36.30	40.82	42.34	118.17	27.82	31.43	38.20	97.52
Std. Dev.	2	10.31	11.04	12.30	26.28	5.80	5.74	6.48	15.29
Avg. Time	3	27.90	32.08	30.50	90.50	23.80	23.54	29.16	76.54
Std. Dev.	3	7.43	9.27	7.38	19.21	6.59	5.01	6.53	15.35
Avg. Time	4	25.75	26.69	28.38	81.13	20.31	22.50	24.56	67.50
Std. Dev.	4	7.28	6.36	6.37	17.01	5.55	6.81	6.93	17.95
Avg. Time	5	23.00	25.33	27.30	75.54	20.42	20.67	24.40	65.48
Std. Dev.	5	6.48	6.95	7.26	19.46	4.88	4.22	5.93	13.31
Avg. Time	6	20.18	24.50	25.75	70.33	20.17	20.75	22.96	63.63
Std. Dev.	6	4.38	5.15	5.85	13.69	3.10	3.73	5.34	10.52

AVERAGE ERRORS AND STANDARD DEVIATIONS

FOR EACH TEST

By Age

	AGE	P-1	P-2	P-3	KD-1	KD-2	KD-3
Avg. Err.	6	4.47	5.87	8.93	1.73	2.07	8.20
Std. Dev.	6	2.39	2.77	4.01	2.28	3.41	6.71
Avg. Err.	7	3.71	5.94	6.41	1.24	3.71	7.82
Std. Dev.	7	3.64	4.02	4.08	1.09	4.58	6.63
Avg. Err.	8	2.32	3.32	4.08	1.12	1.28	1.96
Std. Dev.	8	2.85	3.22	3.66	1.05	3.35	2.68
Avg. Err.	9	1.35	1.30	3.87	1.22	0.48	1.83
Std. Dev.	9	1.61	2.03	2.77	1.41	1.41	2.31
Avg. Err.	10	1.32	2.63	3.00	0.89	0.37	1.05
Std. Dev.	10	1.95	3.27	3.09	0.88	0.60	1.54
Avg. Err.	11	1.30	1.61	3.36	0.64	0.50	1.26
Std. Dev.	11	1.89	2.41	2.65	0.73	1.14	2.61
Avg. Err.	12	0.23	2.47	2.31	0.93	0.67	0.38
Std. Dev.	12	0.44	3.29	3.28	1.79	1.29	0.89

AVERAGE ERRORS AND STANDARD DEVIATIONS

FOR EACH TEST

By Grade in School

	GRADE IN SCHOOL	P-1	P-2	P-3	KD-1	KD-2	KD-3
Avg. Err.	1	4.03	6.11	7.35	1.54	2.85	8.19
Std. Dev.	1	2.91	3.30	4.14	1.86	3.89	7.02
Avg. Err.	2	2.65	3.17	5.87	1.17	1.48	3.09
Std. Dev.	2	2.99	3.24	3.95	0.98	3.01	4.08
Avg. Err.	3	2.08	2.75	4.42	1.33	0.63	2.21
Std. Dev.	3	2.54	3.23	3.28	1.40	1.24	2.40
Avg. Err.	4	1.19	2.00	2.63	0.69	0.38	1.19
Std. Dev.	4	1.80	2.56	3.05	0.89	0.62	1.72
Avg. Err.	5	1.29	2.00	3.29	0.79	0.21	1.00
Std. Dev.	5	2.01	3.70	2.66	0.83	0.41	1.69
Avg. Err.	6	0.46	2.13	2.63	1.38	0.71	0.88
Std. Dev.	6	0.88	3.23	3.06	3.27	1.43	2.31

APPENDIX III

5 3 4 1 6 8 3 0

4 1 6 7 3 5 2 9

7 4 5 8 4 2 9 7

3 9 2 4 6 2 9 4

1 3 4 9 5 1 8 3

JJM TEST