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Comparison of distance rock tests with school children using standard sloan English letter targets versus modified Landolt C targets

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Abstract

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COMPARISON OF DISTANCE ROCK TESTS WITH SCHOOL CHILDREN USING STANDARD SLOAN ENGLISH LETTER TARGETS VERSUS MODIFIED LANDOLT C TARGETS

by

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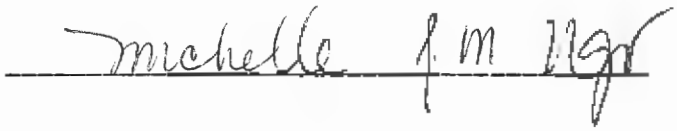
SIGNATURES

Authors:  Michelle P. M. Ngo

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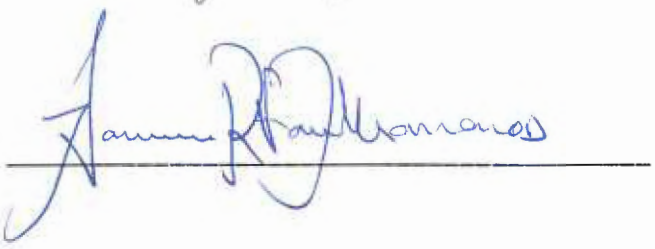
Advisor:  Hannu R. V. Laukkanen, O.D.

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COMPARISON OF DISTANCE ROCK TESTS WITH SCHOOL CHILDREN USING STANDARD SLOAN ENGLISH LETTER TARGETS VERSUS MODIFIED LANDOLT C TARGETS

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ABSTRACT

The distance rock test was first introduced in 1975. Since then there are several studies using the distance rock test at various clinics. So far, English letters have been used as far-near-far targets at 20/80 and 20/25 acuity levels. The tests were administered to children of different age groups. In this study, some aspects of the original Haynes distance rock test such as letter features and target spacing were changed. Specifically, the Landolt Cs were modified and used as new targets in the far-near-far discriminatory tasks. Forty four fourth graders and twenty six first graders were selected for the study. The relative response times of the visual system were measured. The results indicate 1) The fourth graders performed better than the first graders under all possible combinations of the test conditions; 2) Both fourth and first graders called out English letters quicker than Landolt Cs; 3) Fourth graders identified widely spaced Landolt Cs quicker than regularly spaced ones; and 4) Both fourth and first graders called out targets at the 20/80 acuity quicker than those at the 20/25 acuity. Both optometric and psychological factors were considered to explain the students' performance. Automaticity as a function of maturity, practice and learning played a significant role in distance rock responses. Automaticity was shown to be present in distance rock performance since its characteristics were detected in this study. Indications for procedural changes and clinical utilization were also discussed.

KEY WORDS

Distance rock tests, Sloan capital English letters, modified Landolt Cs, automaticity.

I INTRODUCTION

Vision is arguably the most crucial of the human senses. The eyes capture countless images daily. While the eyes respond to near and far stimuli, the brain processes the images and initiates reactions. It has been an interest to researchers and clinicians to measure the relative response times of the normal visual system to shifts from distance to near and back to distance to a discriminatory task. In optometric research, one of the focuses is on the development of a standard distance rock testing procedure and the establishment of the means of relative response time within certain control factors.

I.1 The Distance Rock Test

The distance rock test was first introduced by Harold M. Haynes, O.D. In January 1975, Haynes delivered a preliminary report introducing the distance rock test before the St. Louis Conference On Visual Training and Theoretical Optometry. [Haynes, 79]

The distance rock test was first designed as an experimental procedure for measuring the response time of the visual system shifting from distance to near and back to distance with a set of stationary targets. In this test, all medial distal stimuli (prisms and lenses) remain constant. Proximal stimuli at the fovea are successively changed from a test letter at far to near to far through shifts in eye fixation. Both the far and near test targets are simultaneously present.

Haynes performed the first distance rock experiment on one hundred and eleven college students and clinical patients between the ages of eighteen and thirty five years. English letters were used as targets. The result of the first experiment showed that the mean response times were significantly longer for the 20/25 letters than for the 20/80 sized letters under all conditions. Letter spacing proved a statistically significant variable under monocular and binocular conditions for both the 20/80 and 20/25 acuity targets.

Haynes administered the second distance rock survey on five hundred ninety one school children from grades one through six. Each subject read the 20/25 letters immediately without pause after finishing the 20/80 letters for one minute. The combined response times to read the 20/80 and 20/25 task are summarized in Table 1.

Table 1: Haynes' statistical summary of response times (in cycles per minute) by grades.
(SD stands for standard deviation.)

Grade	Count	Mean	SD	Range
1	83	14	4.39	5 to 32
2	63	17	4.60	7 to 26
3	82	19	5.04	9 to 30
4	148	22	5.02	11 to 38
5	89	24	5.11	12 to 38
6	126	26	5.88	14 to 38

There was wide variation in individual differences among the children both within the same grade and between grades. The wide variations in the response times of the second experiment indicate the influence of variables such as: Fixation change, letter recognization, oral naming, individual visual differences as well as different level of maturation among children. It was also shown that the cycles per minute varied with different inter-letter spacings among other variables.

Differences in measured far-near-far response times are a function of many visual and non-visual variables. Instructions, tasks, modes of response, external physical variables including illumination, target features, etc., along with the distribution of age groups may all contribute to the wide variation of responses.

I.2 Other Research Using The Distance Rock Test

In June 1979, Haynes and McWilliams reported experimental results showing the effects of training on near-far response times as measured by the distance rock test. A significant practice effect for both seventh grade students and optometric students was demonstrated. The average change in elapsed time for students to read one letter at far followed by one at near, or near to far, was shortened at the end of training. The mean improvement from the first to the final testing session for the seventh grade students was 49% (range 15 to 78%), and 40% for the optometry students (range 24 to 60%). [Haynes & McWilliams, 79]

In May 1988, Argenbright and Beaudoin administered Haynes' distance rock test, as well as lens rock and prism rock tests on first graders and fourth graders. However, they measured the response times separately at 20/80 and 20/25 acuity levels. The distance rock means of this study demonstrated the

active maturational process occuring between the first and fourth grade, with the fourth graders performing significantly better. Their distance rock test results are summarized in Table 2. [Argenbright & Beaudoin, 88]

Table 2: Argenbright and Beaudoin's results of distance rock test.
(Mean's unit is cycles per 30 seconds. The unpaired t-test significance at 0.0001.)

Grade	Count	Acuity	Mean	SD
1	87	20/80	6.115	1.701
4	106	20/80	8.443	1.616
1	87	20/25	4.414	1.36
4	106	20/25	6.557	1.574

In November 1991, Jackson and Goss' reported normative data for the following tests: monocular estimate method dynamic retinoscopy, Nott and low neutral dynamic retinoscopy, the binocular cross cylinder test, lens and distance accommodative rock and, negative and positive relative accommodation . Curiously, the distance rock test was performed using 20/20 targets at four meters and the child's habitual reading distance. Each subject was told to alternate fixation from far to near for one minute. The numbers of cycles completed in the first and second 30 second intervals were recorded to the nearest one-half cycle. Table 3 lists the test results. [Jackson & Goss, 91]

Table 3: Jackson and Goss' results of distance rock test.
(The unit is cycles per 30 seconds.)

Distance Rock	< 10 Years		10-12 Years		12-14 Years		14-16 Years	
	M	SD	M	SD	M	SD	M	SD
1st 30 Secs	10.0	3.6	10.8	3.8	10.8	3.6	10.7	2.8
2nd 30 Secs	10.0	3.6	10.7	3.6	10.6	3.6	10.4	2.3

I.3 Automaticity

Throughout the cited research, the performance explanations focus on accommodation, vergence performance, and saccadic eye movement. Previous research has not taken into account the subject's familiarity with the testing targets in explaining the response time. In other words, it has been assumed that optometric factors rather than psychologic factors are the primary performance variables of subject

response time. Letter recognition skills and verbal response times are clearly cognitive activities. It is likely that these activities are influenced by automatic processing (automaticity). [Regan, 81]

LaBerge and Samuels, and Shiffrin and Schneider postulated a capacity central mechanism: attention center, conscious processor and short term store. Any cognitive operation either requires the capacity (space and time) of this central mechanism, or occurs outside this capacity structure. This structure is responsible for strategic control of cognitive operations, that is, voluntary processes. If an action does not require the central mechanism, that action is involuntary or independent of its control. These theorists characterize automaticity as involving rapid, involuntary, parallel processing, as opposed to slow, controlled and sequential processing. [LaBerge & Samuels, 74] [Shiffrin & Schneider, 77]

The theorists who relate automaticity to the existence of a central structure also assert that automaticity only develops after extensive practice. LaBerge and Samuels cited the example of learning to read. Initially, reading is laborious, slow and may proceed on a letter-by-letter basis requiring the attention and storage for each step in the processing sequence. After considerable experience, reading becomes fast, letters are processed in parallel and words may activate their representations without the involvement of the attention center.

I.4 Hypothesis and Experiment Design

An unfamiliar or newly learned symbol should not be processed automatically and therefore should not show the involuntariness and independence of capacity limitations. This non-automatic cognitive processing along with accommodative vergence adjustment would be expected to yield longer response times on a distance rock test with unfamiliar targets. In order to test this hypothesis, a distance rock chart should contain familiar targets such as English letters, and another chart should consist of targets not from the English alphabet. Landolt Cs have been used for acuity testing. Some modifications to Landolt Cs would made them a good choice of unfamiliar targets. The naming of English letters should be at the ceiling of familiarity for elementary students and therefore automatic. On the other hand, newly learned modified Landolt Cs should not be named automatically.

Performance should be examined in mixed sequences of target features to investigate the interaction (in relative response times) of changing task demands with familiarity. In the simple naming English letter task, performance may continue in an automatic fashion even if the acuity level is reduced from 20/80 to 20/25. Yet, more time is required for accommodation at the 20/25 acuity. (This result is confirmed by Haynes, Argenbright and Beaudoin as indicated earlier.) It would be interesting to see if the same result

occured with Landolt Cs on the distance rock test. On the other hand, we would expect naming 20/25 sized English letters should be faster than naming 20/25 sized Landolt Cs because of letter familiarity.

Increasing in the spacing between Landolt Cs at both the 20/80 and 20/25 acuity levels would create a different task demand. With wide spacing, it is expected that the crowding phenomenon would be reduced, and the demand for precise eye movement, fixation, and accommodation would be less . It is expected that the results with wide spaced Landolt Cs would be better than those from regular spaced Landolt Cs test at both acuity levels on a distance rock test.

At any given acuity level, automaticity in terms of letter familiarity should contribute to child's being able to identify letters faster than regular Landolt Cs. Decreased crowding effect should help increase speed in calling out wide spacing Landolt Csas opposed to regular ones. It was estimated that the effect of automaticity would be greater than that of changed intersymbol spacing. Thus, it is expected that the results from the wide spaced Landolt Cs distance rock test would fall somewhere between those of the English letter test and the regular spaced Landolt Cs distance rock tests at both acuity levels.

The above mentioned three separate distance rock tests were administered to fourth and first grade elementary students. The fourth graders were assumed to have more efficient information acquisition and processing abilities. Hence, they would respond quicker than the first graders in the automatic naming of English letters. Similarly, they would take less time to identify the non-automatic of Landolt Cs.

In short, this study was designed to answer three questions:

1 Will specific target features of English letters and modified Landolt Cs affect the relative response times of school children to distance rock tests as measured in cycles per thirty seconds?
2 Will changing demand such as inter-symbol spacing of Landolt Cs affect performance?
3 Will automaticity effects be different between first and fourth grade school children?

II METHOD

II.1 Subject Selection

To address the above questions, with-in-subject field research was conducted from October 1991 to February 1992 at four different elementary schools in Forest Grove and Portland, Oregon. These observations were intended to explore the possible spectrum of response times to three different distance rock tests.

One hundred and twenty school children between the ages of six and ten were examined during the research. In order to be included in our study, each subject had to pass the standard vision screening program administered by the Pacific University, College of Optometry. Each acceptable subject had 20/20 visual acuity at six meters and at forty centimeters in each eye without glasses or with the habitually worn prescription. School children with history of visual pathology or visual dysfunctions identified during the screening were excluded. Any subject who made five or more target identification errors in any test condition were also excluded.

II.2 Target Design

This experiment was designed to determine if a significant response time difference is present for 20/25 and 20/80 acuity sized letters with three distance rock tests. Six cardboard distance and near test charts were designed using the PostScript page description language [Adobe, 91] for precise control. The charts were printed on an Apple LaserWriter and a Varian photoploter as courtesy of Digital Equipment Corp in Palo Alto, California.

The standard letter distance rock test (L) consists of a six meter distance chart and a forty centimeter chart. Each chart has three rows of ten 20/80 Sloan optotype capital letters and three rows of ten 20/25 Sloan letters in an alternating order, starting with 20/80 letters. [Sloan, 51] The Sloan letters were selected based in part on recommendations by Richards. [Richards, 65] Each row was centered on the chart. Five of the ten letters of approximately equal visibility were "curved" letters (ROCSD) and five were "straight" letters (KNHVZ). The "curved" and "straight" letters were arranged to produce distinct rows. The inter-letter spacing or horizontal gap was one-fourth the horizontal width of a 20/80 letter. The inter-row spacing or vertical gap was made one-half the vertical height of a 20/80 letter. This separation is in accord with the recommendations of Fry, Sheppard and Morgan. [Fry, 50] The letter charts were designed as in Figures 1 and 2.

Figure 1: A not-to-scale view of the Sloan letters far chart.

Figure 2: A not-to-scale view of the Sloan letters near chart.

The Landolt C rock test (LC) consists of a six meter chart and a forty centimeter chart. Each chart includes three rows of ten 20/80 modified Landolt Cs and three rows of ten 20/25 Landolt Cs in the alternating order, starting with 20/80 ones. Each row is centered on the chart. The modified Landolt Cs consist of four symbols. The "up" symbol is the capital letter C with the gap facing up. The "down" symbol is the letter C with the gap facing down. The "open" symbol is the capital letter O with top and bottom gaps. The "close" symbol is the letter O. The "up", "down", "open" and "close" symbols were arranged to produce distinct rows on both far and near charts.

The wide spacing Landolt C rock test (WSLC) consists of a six meter chart and a forty centimeter chart. Each chart includes three rows of five 20/80 modified Landolt Cs and three rows of five 20/25 Landolt Cs in the alternating order, starting with 20/80 ones. Each row is centered on the chart. The inter-symbol

spacing is as wide as a sum of a symbol's width and two regular inter-symbol spacings found on the above regular Landolt C rock test.

Appendix A includes the not-to-scale near charts of the wide and regular space Landolt C rock tests.

II.3 Procedure

Three distance rock tests were performed in an alternating order such that no two consecutive subjects viewed the same sequence of tests. A L-WSLC-LC sequence indicated that the Sloan letter distance rock test was administered first, the wide space Landolt C distance rock test second, and the Landolt C distance rock test third.

The distance chart was hung at six meters and the near chart was held by a stand at forty centimeters from a subject. Luminance of both far and near targets was controlled at one hundred foot candles. Both far and near test targets were visible in the field of view.

Before the test, each subject was instructed carefully as to the procedure until he or she understood and was comfortable with the instructions. Starting from the left on the 20/80 line, subjects called out one letter from the distant chart, followed by one letter from the near chart, and so on until all the letters were read on both charts or a "stop" instruction was heard. Subjects were then instructed to call out the 20/25 lines. While reading the charts, subjects kept both eyes open. Each subject was also instructed to call out the conventional English pronunciations of the Sloan letters. For the modified Landolt Cs, the names would be "up", "down", "open" or "close" as described above.

Each distance rock test was conducted in a time frame of thirty seconds. In this time period, the examiner observed and counted the number of far-near-far eye fixations. The numbers of letter substitutions and additions were subtracted from the total number of letters read in thirty seconds. The results reflected the numbers of correctly identified letters. Again, any subject who committed five or more errors was excluded from data analysis.

II.4 Recording

In order to eliminate human errors and to automate the recording process, a recording form was developed. Each form consisted of four sections. The first section contains administration information such as date, school, subject's name, grade level, age, examiner's name, recorder's name and pass/fail indicator. Other three sections correspond to three distance rock tests. Each section has a reduced

versions of the far and near charts for easy tracking of letter substitution, addition and omission. Next to these charts, three sections have identical lines for testing sequence, error computations and the end result numbers.

The total number of correctly identified letters in thirty seconds was divided by two to yield the number of cycles per thirty seconds.

III RESULTS

It was expected that the motor responses for discriminating 20/25 acuity symbols would take longer than for identifying 20/80 acuity symbol because of the necessity for more precise motor adjustments, i.e. accommodation and vergence. By increasing the inter-symbol spacing, the examiners expected to observe a higher number of cycles with the wide space Landolt Cs. Since the school children were more familiar with Sloan letters than the modified Landolt Cs, it was expected that both first and fourth grades would call out the Landolt Cs more slowly than the letters. It was also predicted that fourth graders would call out all target symbols, regarless of size more quickly than first graders.

The following collected data and numerical analysis will help to confirm or contradict the hypothesis.

III.1 Raw Data

The results from twenty six first graders and forty four fourth graders were tabulated for statistical analysis and comparison.

Tables 4 and 5 show the raw data collected during the observations at different elementary schools for the fourth and the first grades, respectively. In each table, the first column indicates the number of subjects, and the second column the test sequence. Since the data were tabulated in alphabetical order of the subjects' first name, some of the consecutive sequences are identical. The third to the fifth column show the cycles per 30 seconds of Sloan letter test, the wide spacing Landolt C test, and the regular Landolt C test at the 20/80 acuity. The sixth to the eighth column show the cycles per 30 seconds of the same order of tests at the 20/25 acuity.

Table 4: Fourth graders' data.

Count	Sequence	L 20/80	WSLC 20/80	LC 20/80	L 20/25	WSLC 20/25	LC 20/25
1	WSLC-LC-L	11.5	9	10	4	5	5
2	WSLC-LC-L	11	7	8.5	4	5.5	4
3	WSLC-L-LC	12	11	12	5	6	2.5
4	WSLC-L-LC	12	8.5	10	7	7	4.5
5	L-WSLC-LC	14	10	10	11	6.5	6.5
6	L-WSLC-LC	13.5	12	9.5	6	5	3
7	L-LC-WSLC	13	13.5	13.5	9	5.5	3.5
8	LC-L-WSLC	13	10	10.5	8	8	4.5
9	LC-L-WSLC	13.5	9	5	7.5	5	4
10	WSLC-LC-L	12	7.5	5	11.5	4	3.5
11	LC-L-WSLC	14.5	14	12	10	8	7.5
12	L-WSLC-LC	12.5	11	11.5	8	4	4.5
13	L-WSLC-LC	20	15	10.5	8.5	11.5	6
14	WSLC-L-LC	11.5	9	9	3.5	4.5	2.5
15	LC-WSLC-L	10	8	6	5.5	4.5	4
16	LC-WSLC-L	10	13.5	9	11	4	5.5
17	L-LC-WSLC	14.5	12	7	7.5	2.5	3.5
18	LC-L-WSLC	9	6.5	4.5	5.5	2.5	3
19	WSLC-LC-L	16	15	15	13.5	12.5	2.5
20	WSLC-LC-L	12.5	13	9	10	7.5	3.5
21	LC-WSLC-L	6	8	7	6	5	4
22	L-LC-WSLC	13	11	6.5	9.5	5.5	9
23	LC-WSLC-L	11.5	10.5	8	9	7	6
24	WSLC-LC-L	8.5	8	9.5	8.5	6	5
25	L-LC-WSLC	12.5	11	10	7.5	8	6.5
26	L-WSLC-LC	9.5	9	7	8.5	4	4.5
27	LC-WSLC-L	10	9.5	9.5	10	7	7
28	L-WSLC-LC	13.5	11	9	7.5	6	7
29	WSLC-L-LC	13.5	10	8	9	5.5	4.5
30	LC-L-WSLC	6.5	5	5.5	5	2.5	3.5
31	LC-L-WSLC	13	17.5	7	4.5	6.5	3
32	WSLC-L-LC	9	10	9	9	7	6
33	WSLC-LC-L	10	12	10	7.5	6.5	5.5
34	LC-WSLC-L	13	13	11.5	10	5.5	7.5
35	L-WSLC-LC	11.5	10	7.5	7	5.5	3.5
36	L-WSLC-LC	15	8	13	8	6	5
37	L-WSLC-LC	10	8	8.5	9	6	4
38	L-WSLC-LC	15.5	8.5	13	9.5	7	4.5
39	WSLC-L-LC	12.5	10	8	7.5	8	4.5
40	LC-WSLC-L	12.5	10	8	9	6.5	4
41	LC-WSLC-L	13.5	10	9	7.5	6.5	5
42	WSLC-L-LC	10	8	7	7	6	5.5
43	LC-WSLC-L	12	11	6	8	4	5.5
44	L-LC-WSLC	11.5	10	8	10	8	4

Table 5: First graders' data.

Count	Sequence	L 20/80	WSLC 20/80	LC 20/80	L 20/25	WSLC 20/25	LC 20/25
1	LC-L-WSLC	7.5	4.5	3.5	6	3.5	3.5
2	L-LC-WSLC	4	6	4.5	2.5	4	3.5
3	WSLC-LC-L	6.5	7	4	5	1.5	1.5
4	L-LC-WSLC	8	8	5	5	2	4
5	LC-L-WSLC	8.5	8	4.5	5	3.5	3
6	WSLC-LC-L	6	6.5	5	2.5	2	4
7	L-LC-WSLC	11	9	6.5	5	4.5	5.5
8	L-WSLC-LC	10.5	10	7	6.5	4.5	3
9	LC-L-WSLC	6.5	6.5	4.5	5	3	2
10	WSLC-LC-L	4.5	6	6.5	2	4	6.5
11	LC-L-WSLC	10	7	4	3.5	4	4
12	WSLC-L-LC	12.5	9.5	10.5	5.5	2.5	3.5
13	L-LC-WSLC	4	6	4.5	2.5	3	2.5
14	WSLC-LC-L	8.5	8	5	4.5	4	3
15	WSLC-LC-L	4	6.5	4	3	2	3.5
16	L-LC-WSLC	9.5	8	5	5.5	6	4
17	LC-WSLC-L	7.5	8	5	5	3.5	2
18	WSLC-L-LC	5.5	5.5	4	3.5	3	3
19	LC-L-WSLC	9.5	9	5.5	5.5	6	5
20	LC-WSLC-L	5.5	7	4.5	4	3	2
21	L-LC-WSLC	8	8.5	5.5	5	3.5	3.5
22	LC-L-WSLC	5.5	5	3	2	1.5	2.5
23	WSLC-LC-L	5.5	3	5.5	3.5	1	2.5
24	L-LC-WSLC	9	5	5	4	4	5
25	LC-L-WSLC	5.5	6.5	5.5	3.5	5	3
26	L-WSLC-LC	7	5.5	6.5	3	4	3.5

III.2 Means and Standard Deviations

All numerical computations were obtained by using the statistic software application *StatView 512+*, from the BrainPower, Inc., running on an Apple Macintosh computer. The *Mean, Std. Dev. and etc.* command

was used to calculate the means and standard deviations. [BrainPower, 86]. Table 6 lists the grade, distance rock test, acuity level, mean, standard deviation, standard error, variance, coefficient of variance, minimum and maximum values. The unit of numeric columns is cycles per 30 seconds.

Table 6: Means and standard deviations of three distance rock tests at the 20/80 and 20/25 acuity levels of 44 fourth graders and 26 first graders.

Grade	Test	Acuity	Mean	SD	SE	Var	CV	Min	Max
FOURTH	Letters	20/80	12.03	2.48	0.37	6.14	20.6	6	20
	WSLC		10.31	2.48	0.37	6.14	24.05	5	17.5
	LC		8.93	2.39	0.36	5.7	26.74	4.5	15
	Letters	20/25	7.95	2.15	0.32	4.64	27.07	3.5	13.5
	WSLC		6.01	1.98	0.3	3.9	32.86	2.5	12.5
	LC		4.73	1.48	0.22	2.2	31.4	2.5	9
FIRST	Letters	20/80	7.31	2.32	0.45	5.38	31.74	4	12.5
	WSLC		6.9	1.66	0.33	2.76	24.07	3	10
	LC		5.15	1.45	0.29	2.12	28.22	3	10.5
	Letters	20/25	4.15	1.29	0.25	1.66	30.97	2	6.5
	WSLC		3.4	1.28	0.25	1.64	37.63	1	6
	LC		3.42	1.15	0.23	1.33	33.74	1.5	6.5

III.3 Data Distribution

To present graphical views of the data distribution, scattergrams were produced using StatView's *View Bar Chart* command [BrainPower, 86]. Appendix B shows twelve graphs. Each graph has a horizontal axis of observations, a vertical axis of cycles per thirty seconds, a mean line and two deviation lines. From Table 6, the standard deviations are quite large as depicted as wide deviation bands around the mean lines on the scattergrams. Six graphs depict the Sloan letter test, the wide spacing Landolt C test and the regular Landolt C test on the fourth graders at the 20/80 and 20/25 acuity levels. Other six graphs are for the first graders.

So far the raw data were tabulated, the mean and standard deviation values were calculated and visualized using scattergrams. Further statistical analysis and comparison are presented in the following sections.

First the focus is geared toward the analysis of data from within a grade level, starting with the fourth grade. Within a grade level, the means are compared at separate acuity level then between both levels. Secondly, the data from both grade levels are compared for cross examination.

III.4 Analysis Of Fourth Graders' Data

StatView's *t-test* command was employed to perform mean comparison. [BrainPower, 86] At a given acuity level, the mean values of the Sloan letter test and the wide space Landolt C test were compared to those of the Landolt C test. Within a distance rock test, the means at both 20/80 and 20/25 acuity levels were compared. The mean differences, probability significance, and paired t values are listed in Table 7.

Table 7: Two-group two-tail paired t-test values of fourth graders.
The degree of freedom is 43, and the unit of means is cycles per 30 seconds.

Fourth Grade	Mean Diff	Prob Sig	t Val
L vs LC 20/80	3.1	0.0001	8.29
WSLC vs LC 20/80	1.38	0.0012	3.47
L vs LC 20/25	3.23	0.0001	9.96
WSLC vs LC 20/25	1.28	0.0005	3.79
L 20/80 vs 20/25	4.08	0.0001	9.94
WSLC 20/80 vs 20/25	4.3	0.0001	12.22
LC 20/80 vs 20/25	4.2	0.0001	10.36

For the fourth graders at the 20/80 acuity, the assumption was that they would identify the Sloan letters quicker than the Landolt Cs. Therefore, the mean of cycles per 30 seconds in reading the Sloan letters was expected to be higher than that in reading the Landolt Cs. The second row of Table 7 shows a positive difference, confirming the hypothesis.

In comparing the means of wide spacing Landolt C test and the regular Landolt C test, Table 7, row 3 shows the positive difference which confirms the hypothesis that it is easier to read the widely spaced Landolt Cs than the regularly spaced ones.

Similar comparisons can be drawn for the fourth graders at the 20/25 acuity. Although the 20/25 size is small, the students were able to identify more letters than Landolt Cs, and more widely spaced Landolt Cs than regularly spaced ones as shown by Table 7, rows 4 and 5.

In comparing performances across acuity levels in the same distance rock test, the fourth graders were able to call out more targets at the 20/80 acuity than those at the 20/25 acuity as indicated in Table 7, rows 6, 7 and 8.

In all cases, the probability is smaller than 0.05 so the results are statistically significant.

An exact comparison of means across three distance rock tests is not feasible because of the nature of the tests. However, a bar chart of column means (Appendix C) shows the highest cycle number with the Sloan letter tests, the medium with the wide space Landolt C tests, and the lowest with the regular Landolt C tests. The chart also reveals an interesting observation: the highest mean at the 20/25 acuity is smaller than the lowest mean at the 20/80 acuity.

StatView's *ANOVA* command was used to perform mean comparison among test sequences. [BrainPower, 86] Table 8 lists means, standard deviations and counts of test sequences. These data are rather informative than statistically significant because the probability is greater than 0.05.

Table 8: Means and standard deviations of the distance rock tests, categorized by testing sequences.

4th Grade	L 80		WSL C 80		LC 80		L 25		WSL C 25		LC 25		C
Sequence	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	
L-WSLC-LC	13.5	3	10.2	2.2	9.9	2.1	8.3	1.4	6.2	2.1	4.8	1.3	10
L-LC-WSLC	12.9	1.1	11.5	1.3	9	2.9	8.7	1.2	5.9	2.3	5.3	2.4	5
WSLC-L-LC	11.5	1.5	9.5	1	9	1.6	6.9	2	6.3	1.1	4.3	1.3	7
WSLC-LC-L	11.6	2.3	10.2	3.1	9.6	2.9	8.4	3.6	6.7	2.8	4.1	1.1	7
LC-L-WSLC	11.6	3.1	10.3	4.7	7.4	3.1	6.8	2.1	5.4	2.5	4.2	1.7	6
LC-WSLC-L	10.9	2.3	10.4	1.9	8.2	1.8	8.4	1.9	5.6	1.2	5.4	1.3	9
Prob Sig	0.25		0.87		0.36		0.38		0.85		0.44		

III.5 Analysis Of First Graders' Data

Again, StatView's *t-test* command was used to compare mean values. [BrainPower, 86] At a given acuity level, the mean values of the Sloan letter test and the wide space Landolt C test were compared to that of

the Landolt C test. Within a distance rock test, the means at both 20/80 and 20/25 acuity levels were compared. The mean differences, probability significance, and paired t values are listed in Table 9.

Table 9: Two-group two-tail paired t-test values of first graders.
The degree of freedom is 25 and the unit of means is cycles per 30 seconds.

First Grade	Mean Diff	Prob Sig	t Val
L vs LC 20/80	2.15	0.0001	5.62
WSLC vs LC 20/80	1.75	0.0001	5.62
L vs LC 20/25	0.73	0.0504	2.06
WSLC vs LC 20/25	- 0.02	0.939	- 0.08
L 20/80 vs 20/25	3.15	0.0001	9.8
WSLC 20/80 vs 20/25	3.5	0.0001	11.03
LC 20/80 vs 20/25	1.73	0.0001	5.69

For the first graders at the 20/80 acuity, the hypothesis was that they would be able to call out Sloan letters easier than the Landolt Cs. Hence, the mean of the Sloan letter test would be higher than that of the Landolt C test. It was also assumed that the wide space Landolt C target was easier to read than the regular one. Rows 2 and 3 of Table 9 indicate positive differences of mean values. This confirms the hypothesis.

At the 20/25 acuity, the first graders could discriminate letters better than Landolt Cs. Table 9, row 4 shows a positive mean difference. In contrast to the assumption, the result shows that first graders could identify regularly spaced Landolt Cs easier than widely spaced ones. Table 9, row 5 shows a negative difference.

For the first three cases, the probability is smaller than 0.05 so the results are statistically significant. Yet, the fourth case shows a probability level higher than 0.05. So the fourth mean difference is not significant.

In comparing performances at two acuity levels in the same test, Table 9 (rows 6, 7 and 8) shows that first graders could call out more targets at the larger size. The probability values are smaller than 0.05; thus, the results are significant.

Because of the features of the tests, the mean values of three tests cannot be compared directly. The bar chart of column means (Appendix D) shows the highest cycle number with the Sloan letter test, the medium with the wide space Landolt C test, and the lowest with the regular Landolt C test. However, the mean of wide space Landolt C test is unexpectedly low. The highest mean of 20/25 acuity is smaller than the lowest mean of 20/80 acuity.

StatView's *ANOVA* command was used to perform mean comparison among test sequences. [BrainPower, 86] Table 10 lists means, standard deviations and counts of test sequences. These data are rather informative than statistically significant because the probability is greater than 0.05.

Table 10: Means and standard deviations of the distance rock tests, categorized by testing sequences.

1st Grade	L 80		WSL C 80		LC 80		L 25		WSL C 25		LC 25		C
Sequence	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	
L-WSLC-LC	8.8	2.5	7.8	3.2	6.8	0.4	4.8	2.5	4.2	0.4	3.2	0.4	2
L-LC-WSLC	7.6	2.7	7.2	1.5	5.1	0.7	4.2	1.3	3.9	1.2	4	1	7
WSLC-L-LC	9	4.9	7.5	2.8	7.2	4.6	4.5	1.4	2.8	0.4	3.2	0.4	2
WSLC-LC-L	5.8	1.6	6.2	1.7	5	0.9	3.4	1.2	2.4	1.3	3.5	1.7	6
LC-L-WSLC	7.6	1.8	6.6	1.6	4.4	0.9	4.4	1.4	3.8	1.4	3.3	1	7
LC-WSLC-L	6.5	1.4	7.5	0.7	4.8	0.4	4.5	0.7	3.2	0.4	2	0	2
Prob Sig	0.47		0.79		0.09		0.75		0.26		0.44		

III.6 Cross Analysis Of Data Between Fourth and First Grades

Previous sections are for analyzing the result data within groups of students, the following sections are devoted to comparing the results between groups.

StatView's *ANOVA* command was used to compare the means between two grade levels for each distance rock test at each acuity level. [BrainPower, 86] Table 11 lists the mean differences between fourth and first grades. Since the probability is smaller than 0.05, the results are more than 95% significant.

Table 11: Single factor-factorial analysis of variance (ANOVA):
test means as functions of grade levels.

Fourth Grade vs First Grade		Mean Diff	Prob Sig
Letters	**20/80**	4.73	0.0001
WS Landolt Cs	**20/80**	3.4	0.0001
Landolt Cs	**20/80**	3.78	0.0001
Letters	**20/25**	3.8	0.0001
WS Landolt Cs	**20/25**	2.61	0.0001
Landolt Cs	**20/25**	1.3	0.0003

The second column of Table 11 lists the positive mean differences of response times of all six distance rock tests. This consistency indicates that the fourth graders responded quicker than the first graders in all far-near-far discriminating tasks.

Appendix E shows a chart of twelve bars for comparing fourth and first graders' mean response times of the distance rock tests. This chart is the combination of charts in Appendices C and D. It is interesting to observe that the highest mean of the first grade is smaller than the smallest mean of the fourth grade.

III.7 Result Summary

To summarize the results, mathematical notations are used. Inequality $a > b > c$ is used to denote quantity a is greater than quantity b which is greater than quantity c. It is inferred that quantity a is greater than quantity c.

The notations **l**, **wslc** and **lc** denote the numbers of cycles per thirty seconds of the Sloan letter test, the wide spacing Landolt C test, and the regular spacing Landolt C test, respectively. Subscripts 80 and 25 are used to denote 20/80 and 20/25 acuity levels, respectively. Subscripts 4 and 1 denote fourth and first grader, respectively.

Note: a greater number of cycles per thirty seconds means that the relative response time (say per cycle) of that distance rock test is shorter.

The following table depicts the relative comparisons across all categories.

Table 12: Result summary in relative terms.

Fourth grade, 20/80 acuity	$I > wslc > Ic$
Fourth grade, 20/25 acuity	$I > wslc > Ic$
Fourth grade, 20/80 vs 20/25	$I_{80} > wslc_{80} > Ic_{80} > I_{25} > wslc_{25} > Ic_{25}$
First grade, 20/80 acuity	$I > wslc > Ic$
First grade, 20/25 acuity	$I > Ic > wslc$
First grade, 20/80 vs 20/25	$I_{80} > wslc_{80} > Ic_{80} > I_{25} > Ic_{25} > wslc_{25}$
20/80 acuity, fourth vs first	$I_4 > I_1$, $wslc_4 > wslc_1$, $Ic_4 > Ic_1$
20/25 acuity, fourth vs first	$I_4 > I_1$, $wslc_4 > wslc_1$, $Ic_4 > Ic_1$

IV DISCUSSION

The above result summary table seems to confirm the hypothesis postulated in the introduction section except for the case of first graders at the 20/25 acuity level using the regular and wide spaced Landolt C tests. The first graders could identify regular spaced Landolt Cs quicker than the wide spaced ones at the 20/25 acuity level. However, this exception is dismissed since its associated data are insignificant, and should not be included in the following discussion.

The following section will try to link the results of this study with the original hypothesis and explore the optometric and psychologic impact and significance of this study.

To better understand the demand of the distance rock test, a task analysis sequence for one far-near-far cycle is outlined as follows:

1 The eyes start out by looking at a far distance rock chart. They go through a series of accommodation, vergence, fixation and refixation interactions to acquire a far target.
2 Cognitive processing of the image takes place. Then a verbal naming of the image is initiated.
3 The eyes move to the near distance rock chart and go through the series of accommodation as well as accommodative/vergence functions , fixaton and refixation to acquire a near target.
4 Another cognitive operation occurs to interpret the target, resulting in a verbal indication.
5 The sequence starts over for the next target.

A distance rock performance is undoubtedly affected by the distal/proximal stimuli, refractive variables, motor variables, initial processing time, form detection, letter recognition skills, and verbal response time. Let us consider the optometric issues first.

IV.1 Optometric Considerations

Once a subject has just fixated a far target, his visual system is at the infinity state. In this relaxed state, accommodation, accommodative convergence and convergence decrease. When the eyes are on a target, it is known as a fixation. When the eyes are looking for a particular target, the eye movement is called an involuntary refixation or saccadic movement. When the retinal image has fallen correctly on the fovea or when the subject can see clearly and singly, the information is transmitted to the brain from the visual cortex.

The brain has then initiated a new integrated neuromuscular activity and developed a motor verbal response. This cognitive process involves central processing or it can occur automatically. The cognitive matter deserves its own discussion later but it undoubtedly contributes to the overall relative response time.

When a subject has fixated a near target, convergence is stimulated and increases. Hofstetter thought of this proximal convergence as awareness of nearness. [Hofstetter, 51] When convergence increases, accommodation also increases because the eyes try to maintain clearness and singleness of the target for single binocular vision.

The numerous visual adjustments vary from one individual to another even on the same test. Twelve scattergrams of Appendix B show wide data distribution on any given distance rock test. Note that our measurements were made by counting the correct answers during a given time period. Accommodation speed, vergence eye movement and data processing speed were not measured directly. Only the response times were computed to yield a norm by using the distance rock test within certain controlled parameters. However, a certain consistency can be extracted from these widely distributed test results.

Accommodative/vergence performance is measured by subjecting the eyes to distal and proximal stimuli. Two criteria of the distance rock test are acuity level and inter-target spacing. For either fourth or first grade, all three distance rock results at the 20/80 acuity level are better than those at the 20/25 level (rows 6, 7, and 8 of Tables 7 and 9). Similarly, for either grade, the results from the wide space Landolt Cs are better than those of the regular spaced Landolt C tests at both acuity levels (rows 2, 3, 4, and 5 of Tables 7 and 9).

The Landolt Cs were new to the children but they could see better at the 20/80 acuity level. Clearly, the 20/25 acuity targets require a higher demand level with Landolt Cs. This suggests that the size effect has some influence on one's ability to fixate a target. Therefore, more eye adjustments were required, resulting in delayed namings.

Wider spacing eased the demand with Landolt Cs. Since there are only five Landolt Cs on each row, it took less time to keep track of the location (saccadic movement) and allowed more time for focusing on the target (accommodation/vergence system). As a result, fourth and first graders identified more wide spaced Landolt Cs than regular spaced ones. Therefore, the differences are likely a function of eye movements, fixation quality, and letter crowding phenomenon.

Overall, the fourth graders performed better than the first graders in all test conditions as shown in Table 11 and graphically depicted in Appendix E.

Appendix F represents two tables of correlation matrix for the fourth and first graders indicating that there is no direct relationship among testing conditions in each group. The majority values of correlation matrix for the fourth graders depicted less than 0.6 ; therefore, the fourth graders represent a strong independent level between any sets of testing condition of the study. The correlation matrix for the first graders had three values greater than 0.6 out of fifteen sets of any two variables. As a result, the first graders not represent reasonably strong relationship in the study.

Comparison To Other Research

The standard distance rock numerical data from this study cannot be compared directly to those of Haynes because of a different timing and recording procedure were in the two studies, although the same test targets were used for test condition. However, Haynes' research and this study agree on the following points: [Haynes, 79]

1 The mean response times are significantly longer for the 20/25 letters than for the 20/80 sized letters even with different inter- target spacing and at different grade levels.
2 Letter spacing is a statistically significant variable on performance under binocular conditions for both acuity levels and grades.

A portion of the data from this research can be compared to Argenbright and Beaudoin's letter distance rock test data. The data are listed side by side in Table 13.

Table 13: Comparison of Sloan letter distance rock tests' results.

		Argenbright	& Beaudoin	Ngo &	Huynh
Grade	Acuity	Count	Mean	Mean	Count
4	20/80	106	8.443	12.03	44
4	20/25	106	6.557	7.95	44
1	20/80	87	6.115	7.31	26
1	20/25	87	4.414	4.15	26

The means of this study are higher than those of Argenbright and Beaudoin. Argenbright and Beaudoin collected data from almost twice the number of students in both grade levels as this study. Since a mean value is sensitive to the extreme scores, a smaller number of samples with a few large values could affect the mean significantly. This could explain the differences in mean values.

On the other hand, the increase in performance from first to fourth grade and from the 20/25 to 20/80 acuity level suggests the same conclusion as drawn by Argenbright and Beaudoin. That is, the mean response times are significantly longer for 20/25 letters than for 20/80 sized letters, and longer for the younger children than the older children. [Argenbright & Beaudoin, 88]

This study and that of Jackson and Goss have different testing protocols; thus, a direct comparison can not be made. Some similar psychological factors are discussed in the next section.

IV.2 Psychological Considerations

This section revisits the issues of automaticity and the central processing mechanism.

Automaticity has been tied to the issue of whether or not the information processing system utilizes a central attention-processor-capacity structure. Automatic processes have been described as capacity free because they do not require the space or time of the central processor. They are involuntary because they are not subject to the strategic control of the central processor, but they require extensive practice to establish. [Regan, 81]

This research was planned in part to test for the presence and effect of automaticity involved in the distance rock test. We tried to detect the characteristics of automaticity. We also tried to determine

whether extensive practice is a necessary condition for automaticity. Generally, it was expected that processing of familiar items would show evidence of capacity-free and involuntary processing, whereas processing of unfamiliar items would not. [Regan, 81] The data for English letters and landolt Cs in all conditions of the study are consistent with the hypothesis that extensive practice is a necessary condition for automaticity.

It was expected that discrimination of known targets would show evidence of capacity free and involuntary processing, whereas identifying unfamiliar targets would not. Therefore, the response time calling out familiar targets would be relatively shorter. In other words, children should call out English letters faster than Landolt Cs. The cycle numbers of the English letter distance rock tests in all tested permutations of acuity levels, spacing demands and grade levels are consistently and significantly shorter than those of the Landolt C tests. The numbers of cycles for English letters are about 30% higher than those of the Landolt Cs (Table 6).

Subjects known to be familiarity with certain targets would not be expected to show signs of latency in identifying those target. Fourth graders, who have learned to read and write for at least four years, could voluntarily call out more English letters than first graders, who have been only exposed to the English alphabet during the past year, in the same period of time (about 40%). Fourth graders' naming of English letters is automatic since they already know the targets and verry little time is used to match the letters' forms and produce the names. (Table 11)

Naming Landolt Cs obviously requires the central capacity where symbol-name associations reside and the control of mapping symbols to their associated names for verbal responses. This explains the delays in response time as supported by the data of both fourth and first graders (rows 2 and 4 of Tables 7 and 9).

The differences in performance between two grades are a function of automaticity and target familiarity. In summary, the results of this study confirms the influence of automaticity on the distance rock test.

Comparison To Other Research

Haynes did not discuss the potential influence of psychological factors in his study. However, his conclusion that the relative response time improves with ages in elementary school children reflects to the same presence of automaticity may represent both perceptual learning and response learning. [Haynes, 79]

Argenbright and Beaudoin touched on the visual/cognitive subskills but did not explore the impact of automaticity since their study was designed to investigate correlation between lens rock, prism rock, and distance rock tests. Their results from English letter distance rock (Table 2) agree with those from this study. [Argenbright & Beaudoin, 88]

Since this study differs from that of Jackson and Goss in acuity levels and age distribution, the numerical results cannot be compared. But again, their measurements (Table 3) suggest the presence of certain target familiarity levels with the older children.[Jackson & Goss, 91]

IV.3 Procedural Considerations

The modified Landolt Cs with gap facing left and right were not used in this study in order to decrease the laterality demand. Laterality is an inner awareness of left as different from right, not only just knowing the names of the two sides. Cratty's observations indicate that letter reversal tendencies are expected in normal children up to eight years of age. [Cratty, 70] Consequently, the left and right opening Landolt Cs would be more difficult to identify for the first graders than for fourth graders.

During the testing time, the examiners observed that several children had called out the "close" Landolt C as the letter O. Since it originally was not designed to count this substitutions as mistakes, there is no exact number of mistakes. However, this observation brings up an interesting point in cognitive processing. Since the letter O was used in the Sloan letter distance rock tests, the "close" Landolt C immediately activated its English representation without the subject's intention. In addition, the subject is more familiar with English letters so the O representation led to the interference. This is a strong indication of capacity free and involuntary processing, therefore automaticity is present. As a side effect, it is strongly suggested that new targets should be used in different distance rock tests in the future.

Although many first graders were screened, only twenty six were accepted for this study. This small number of subjects might explain the decrease in their overall performance. Also, twenty six is significantly smaller than forty four fourth graders. It would have been better if numbers of fourth and first graders had been the same.

IV.4 Clinical Considerations

Haynes pioneered the work on the distance rock test in 1975. At that time there was series of initial investigations to establish the test as a standard testing procedure. [Haynes, 79] Four years later, the first application of the distance rock test on training of near-far response time was reported. [Haynes &

McWilliams, 79] In both cited papers, the results were encouraging for more data collection and further research into other aspects of the distance rock test.

Argenbright and Beaudoin, and Jackson and Goss independently contributed data and further investigated various factors of visual response using the distance rock tests.

This study was planned to extend that research direction set forward by Haynes. In particular, the study investigates the far-near-far relative response times with a different set of targets, namely the modified Landolt Cs, with elementary school children. The findings of the Haynes distance rock test were also confirmed and used as the basis for comparison with new results acquired using the modified Landolt C distance rock tests. And the numbers of the Landolt C tests are proven to be reliable.

The results of the Landolt C rock tests can help establishing clinical and survey standards for fourth and first graders at 20/80 and 20/25 acuity levels. The feasibility is suggested here, but differences in the test protocols, the procedures, and the measurements need to be standardized. The degree to which accommodative/vergence are factors in performance could be investigated in the future by comparing monocular results to binocular results with the distance rock test. Therefore, more extensive work would be needed to establish the distance rock test as a standard in general and the Landolt C distance rock test as an alternative. Once established, they would offer tremendous benefit as a clinical tool for measuring far-near-far response time. This would be a quick simple vision screening test of the eyes' reaction to a distance-near-distance discriminatory task. The result would help clinicians to start further diagnostic analysis.

V SUMMARY

Different aspects of the original distance rock test have been studied in this research. The traditional English letters were replaced by a newly modified Landolt C targets. In addition, spatial demands were varied to measure the relative response times of the human visual system to different far-near-far identification targets.

Data were gathered from fourth and first graders were subjected to extensive statistical analysis and cross examination. It was found that: (1) fourth graders perform better than first graders in all test conditions; (2) within each grade, the students identify English letters quicker than Landolt Cs; and (3) larger targets and widely spaced target symbols are easier to recognize than smaller crowded symbols.

REFERENCES

[Adobe, 91] Adobe Systems, Inc.: *PostScript Language Reference Manual, Second Edition.* Addison-Wesley Publishing Company, Inc., Menlo Park, CA. 1991.

[Argenbright & Beaudoin, 88] Argenbright, Bret F.; Beaudoin, Clifford A.: *Clinical Norms for Evaluation of Accommodative Facility, Vergence Facility and Accommodative/Vergence Facility.* Thesis on file in the library of Pacific University, College of Optometry, Forest Grove, OR. 1988.

[BrainPower, 86] BrainPower, Inc.: *StatView 512+: The Professional, Graphic, Statistics Utility.* Abacus Concepts, Inc. 1986.

[Cratty, 70] Cratty, B. J.: *Perceptual and Motor Development in Infants and Children.* The MacMillan Co.; London, N.Y.; 1970; pp 109-110.

[Haynes, 79] Haynes, Harold M.: The Distance Rock Test - A Preliminary Report. *Journal of the American Optometric Association.* 50(6): 707-713, June 1979. (Paper was first read before the St. Louis Conference On Visual Training and Theoretical Optometry in January 1975.)

[Haynes & McWilliams, 79] Haynes, Harold M.; McWillimas, Lynn G.: Effects Of Training On Near-Far Response Time As Measured By The Distance Rock Test. *Journal of the American Optometric Association.* 50(6): 715-718, June 1979.

[Hofstetter, 51] Hofstetter, H. W.: The Relationship of Proximal Convergence to Fusional and Accommodative-Convergence. *American Journal of Optometry and Archives of the American Academy of Optometry.* 28: 300, 1951.

[Jackson & Goss, 91] Jackson, Tonya W.; Goss, David A.: Variation and Correlation of Clinical Tests of Accommodative Function In A Sample of School-Age Children. *Journal of American Optometric Association.* 62(11): 857-866, 1991.

[LaBerge & Samuels, 74] LaBerge, David and Samuels, S. Jay: Toward a Theory of Automatic Information Processing in Reading. *Cognitive Psychology.* 6, 293-323, 1974.

[Regan, 81] Regan, Joan E.: Automaticity and Learning: Effects of Familiarity on Naming Letters. *Journal of Experimental Psychology, Human Perception and Performance.* 7(1): 180-195, 1981.

[Richards, 65] Richards, O.: A Comparison of Acuity Test Letters With And Without Serifs. *American Journal of Optometry and Archives of the American Academy of Optometry.* 42(10): 589-592, October 1965.

[Shiffrin & Schneider, 77] Shiffrin, R. M. and Schneider, W.: Controlled and Automatic Human Information Processing: Perceptual Learning, Automatic Attending, and a General Theory. *Psychology Review.* 84, 1-66, 127-190, 1977.

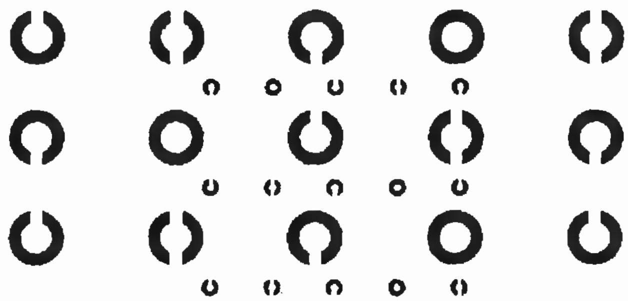
[Sloan, 51] Sloan, L.: Measurement Of Visual Acuity. *Arch Ophth.* 45(6): 704-725, June 1951.

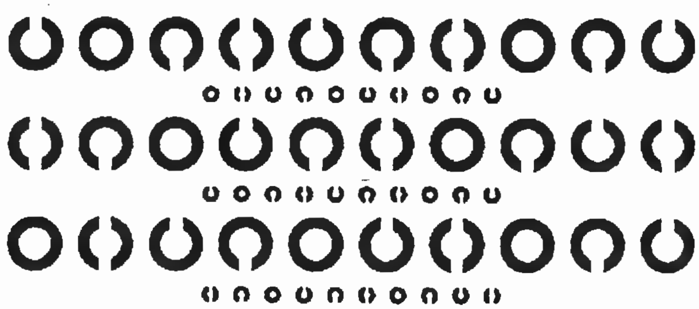
ADDITIONAL REFERENCES

Mackner, Jeffrey L.; Onorato, Steven J.: *Accommodative Facility: Assessment of Variables Limiting Performance.* Thesis on file in the library of Pacific University, College of Optometry, Forest Grove, OR. 1991.

Solan, Harold A.; Suchoff, Irvin B.: *Tests and Measurements For Behavioral Optometrists.* Optometric Extension Program Foundation, Inc. Santa Ana, CA. 1991.

APPENDIX A: The Not-To-Scale Views of the Near Charts of the Wide Space Landolt C Distance Rock Test and the Regular Space Landolt C Distance Rock Test.





APPENDIX B: Data Distribution

There are twelve scattergrams divided into four sets. The sets are

the fourth grade 20/80 distance rock tests,

the fourth grade 20/25 distance rock tests,

the first grade 20/80 distance rock tests, and

the first grade 20/25 distance rock tests.

Each set has three graphs for

the Sloan letter test,

the wide spacing Landolt C test, and

the Landolt C test.

Each graph has

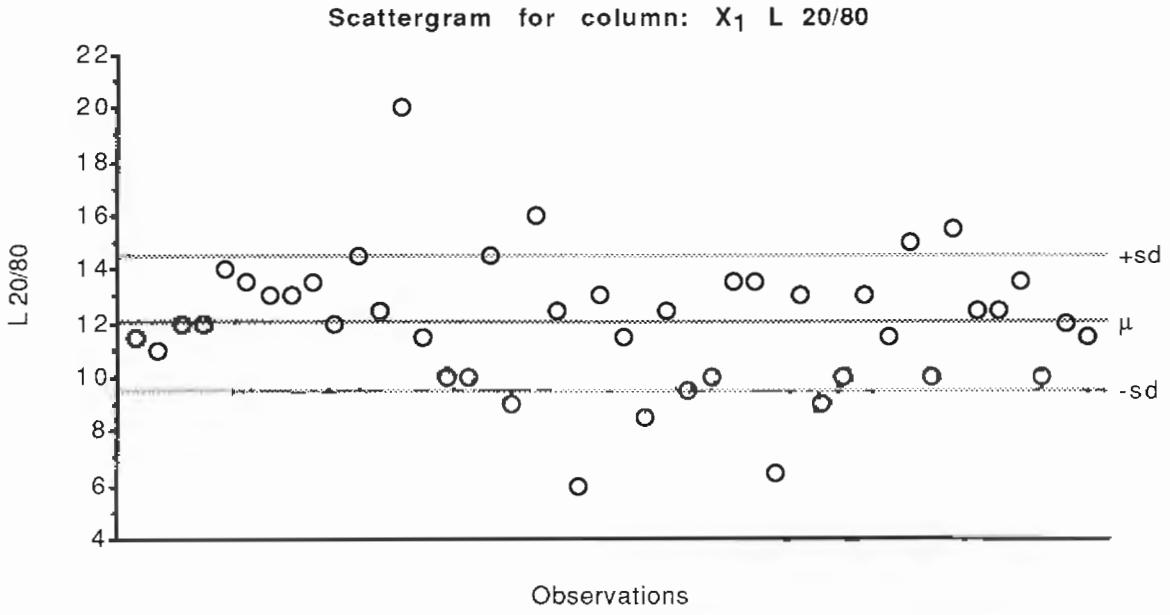
a horizontal axis of observations,

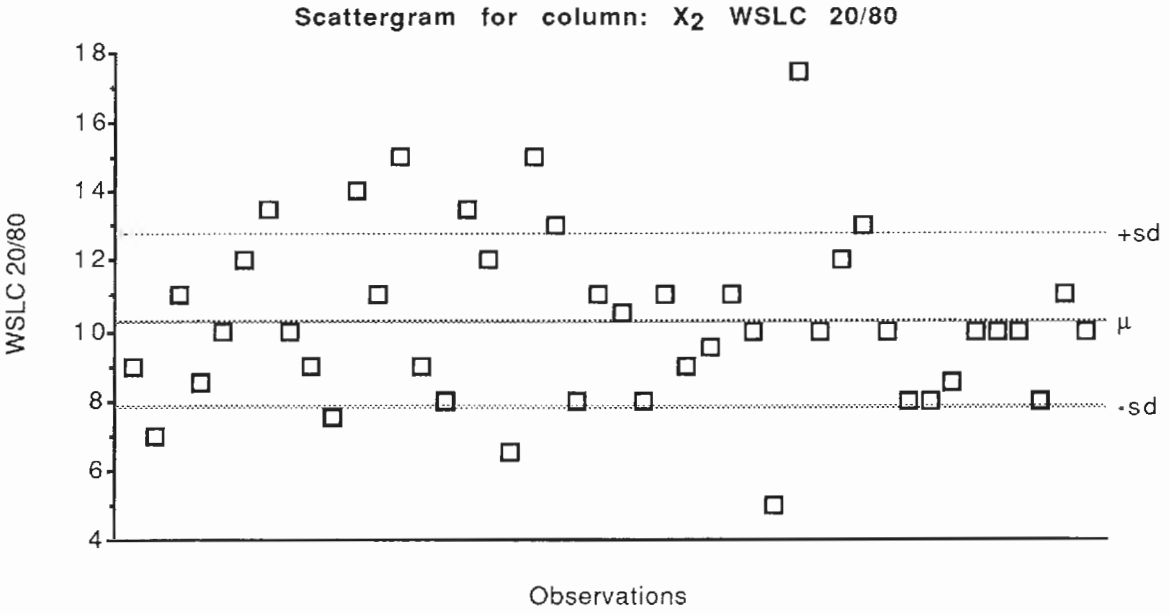
a vertical axis of cycles per thirty seconds,

a mean line, and

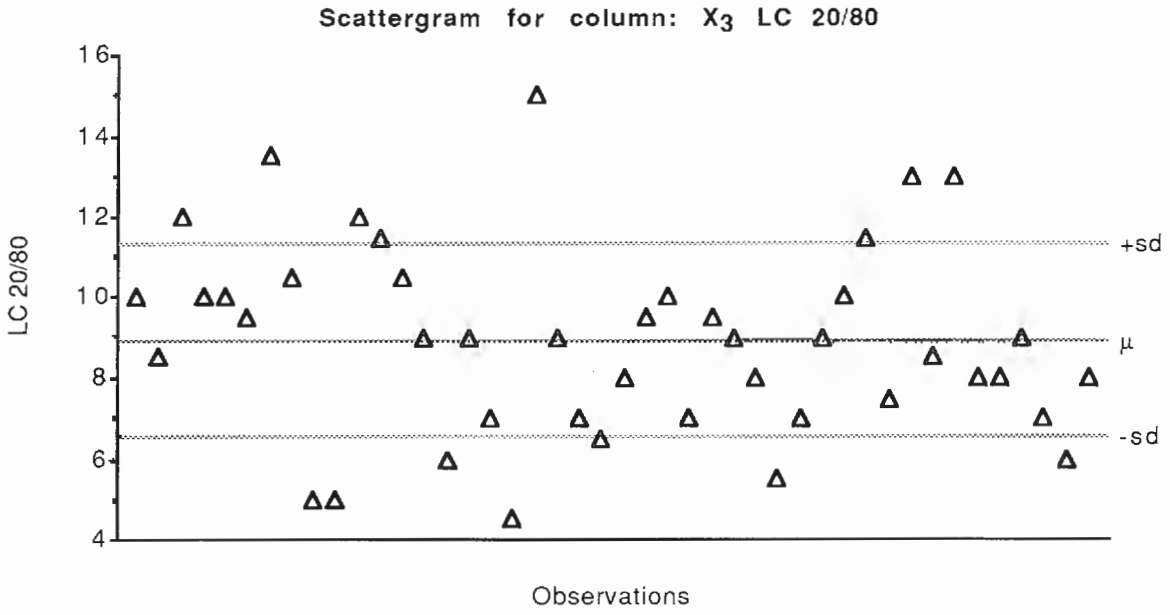
two deviation lines.

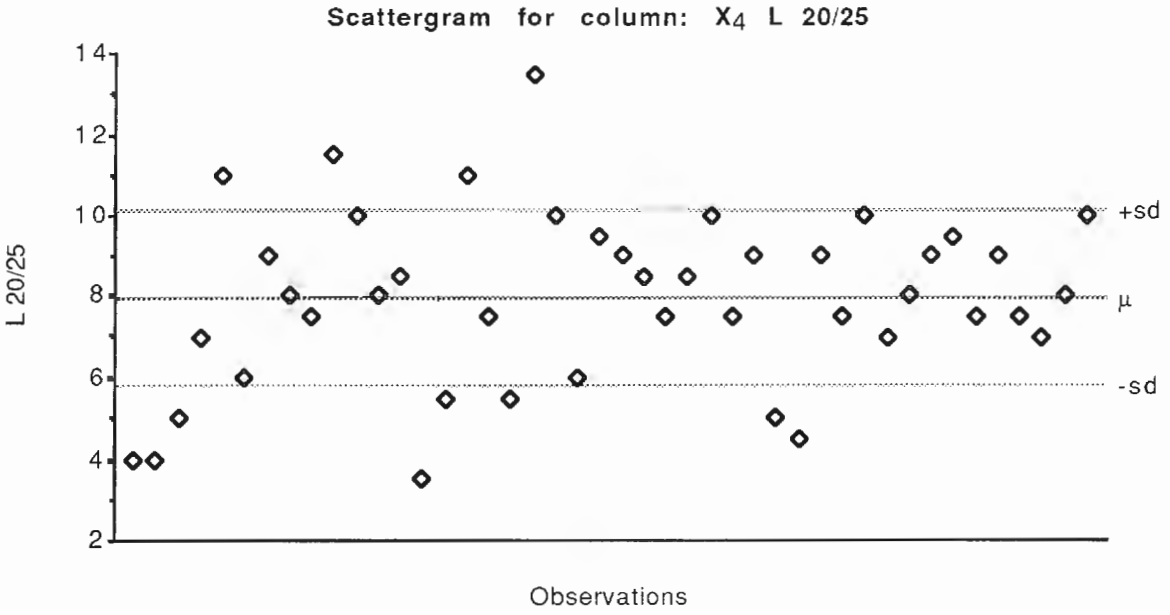
Data Distribution of Fourth Graders' Response Times



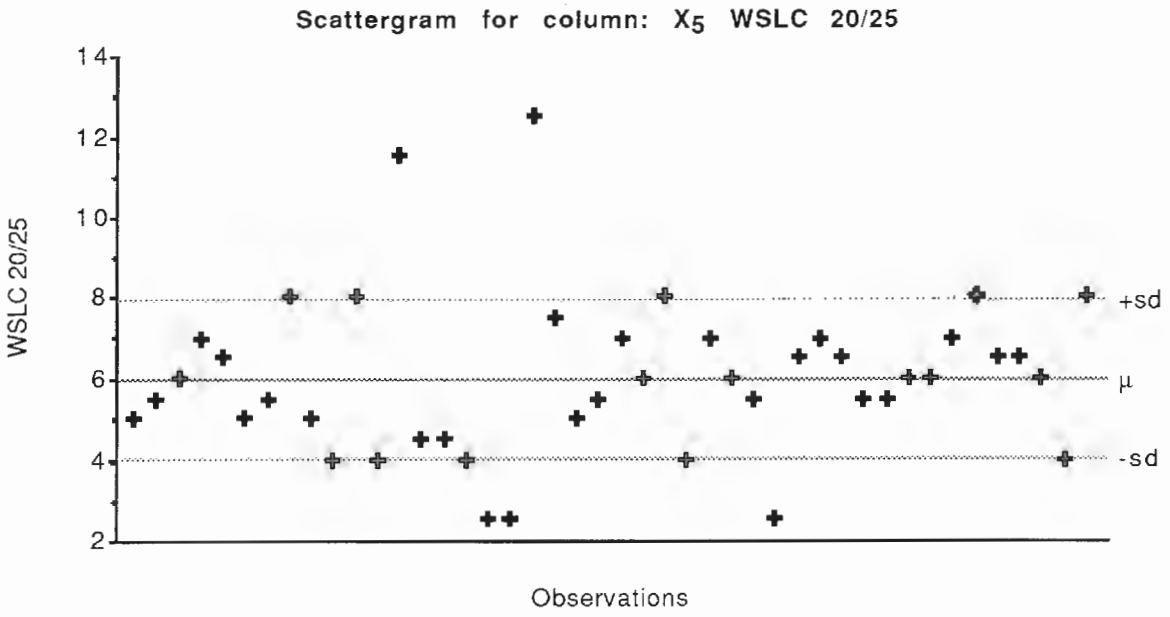


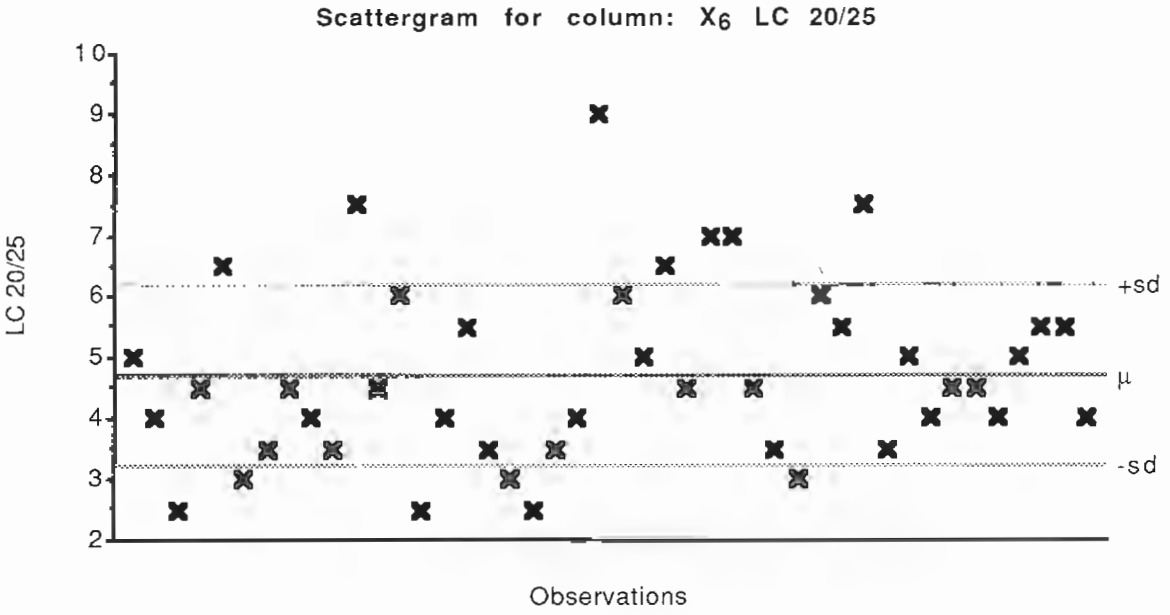
Data Distribution of Fourth Graders' Response Times



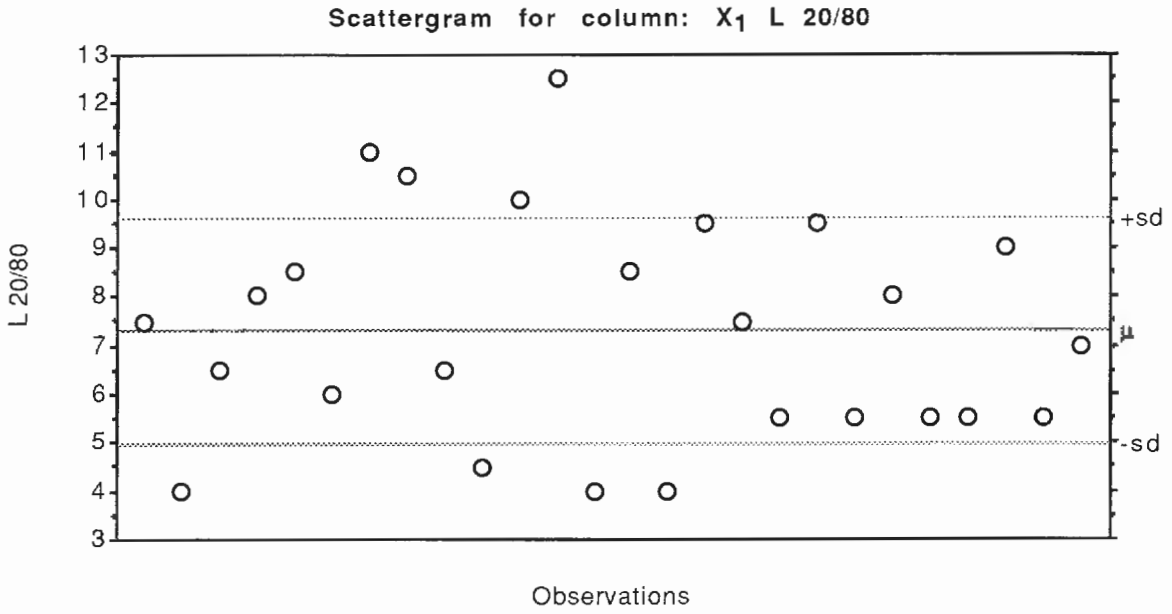


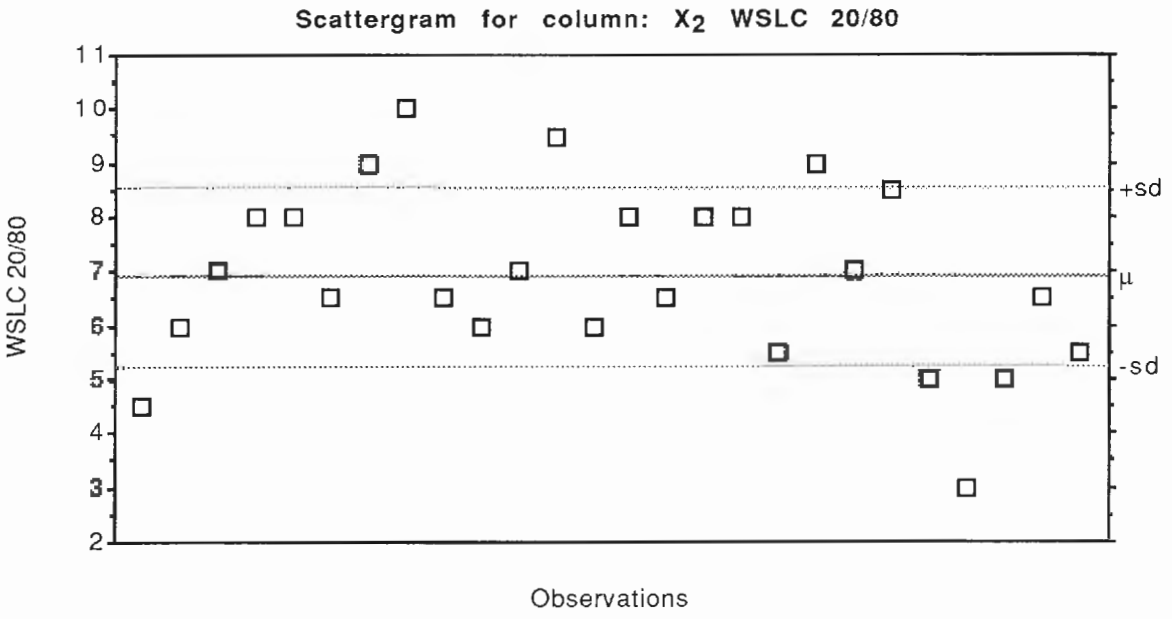
Data Distribution of Fourth Graders' Response Times



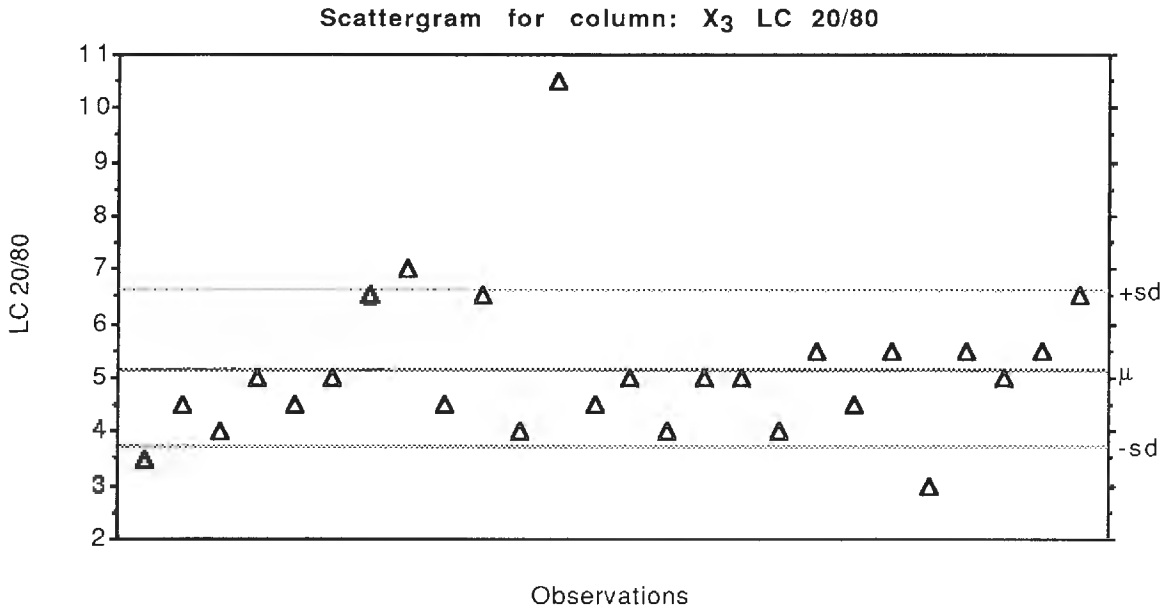


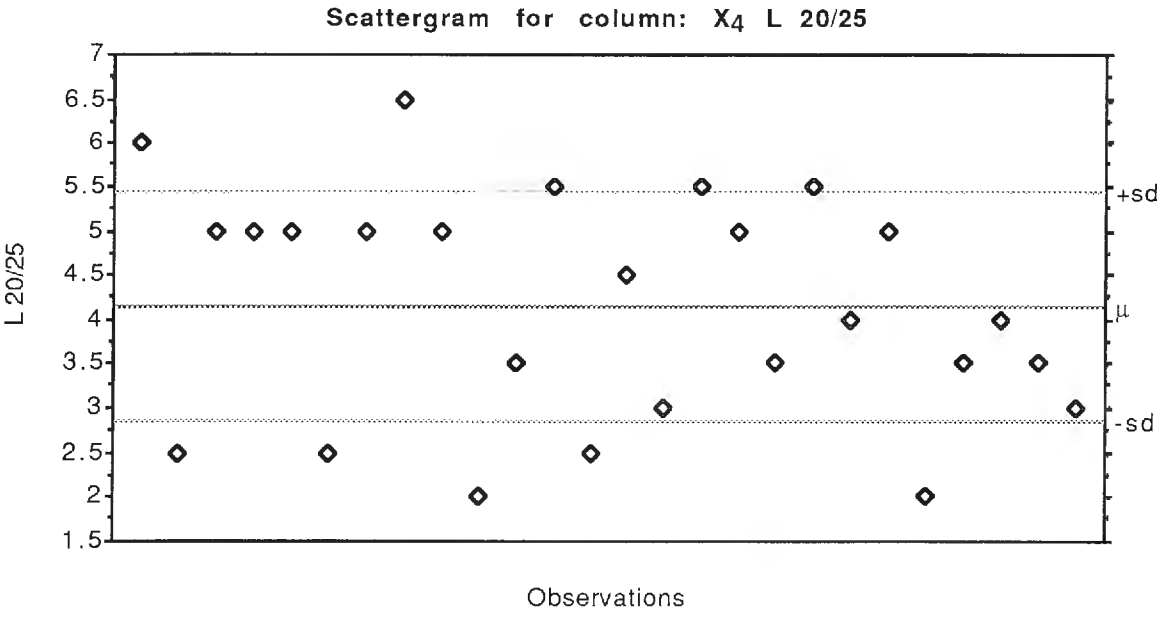
Data Distribution of First Graders' Response Times



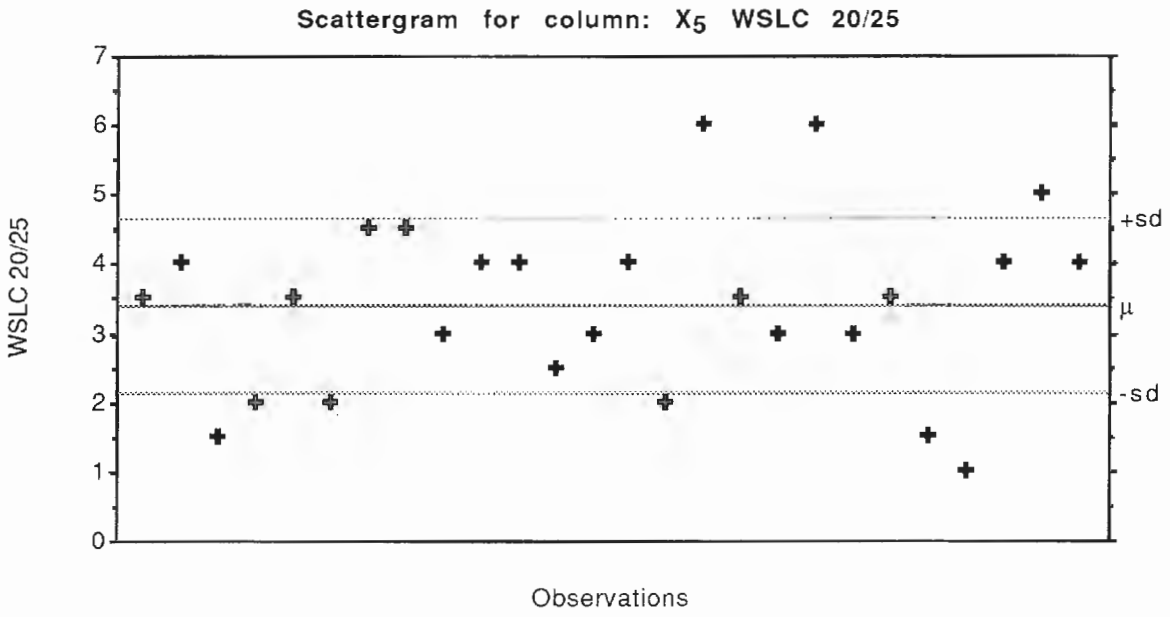


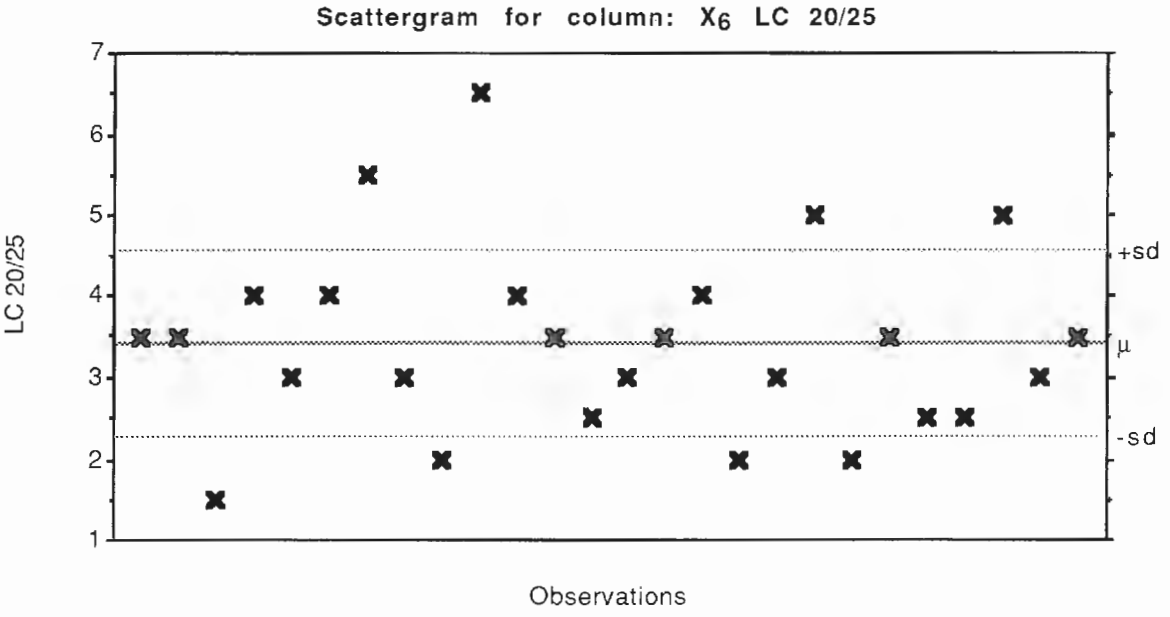
Data Distribution of First Graders' Response Times





Data Distribution of First Graders' Response Times





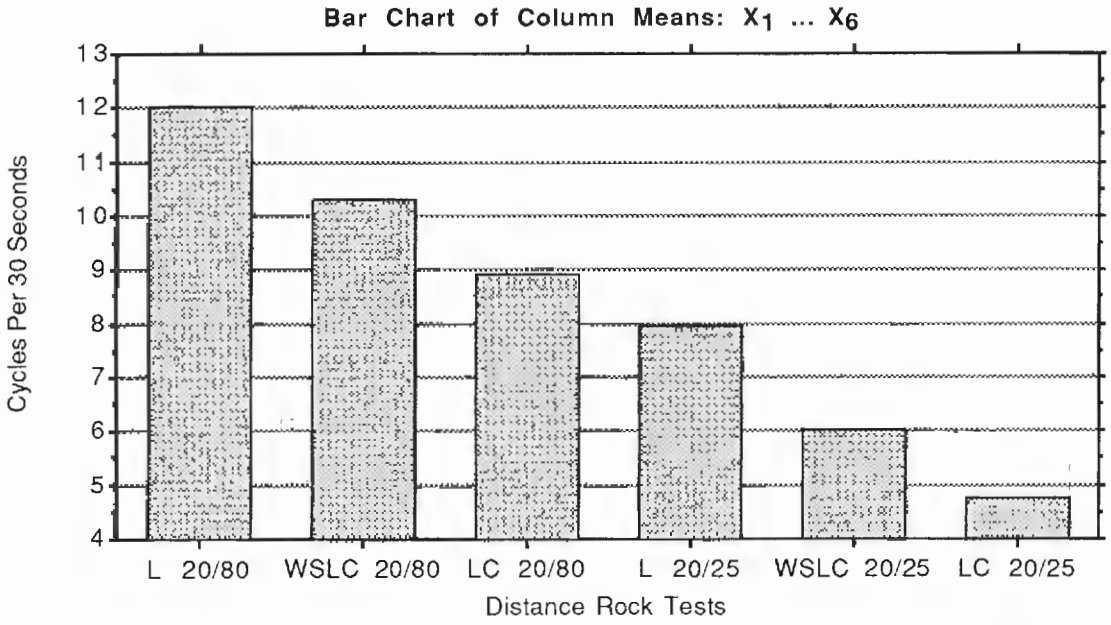
APPENDIX C: Comparison of Fourth Graders' Performance Means

The bar chart has

a horizontal axis of distance rock tests, and

a vertical axis of cycles per thirty seconds.

Comparison of Fourth Graders' Performance Means



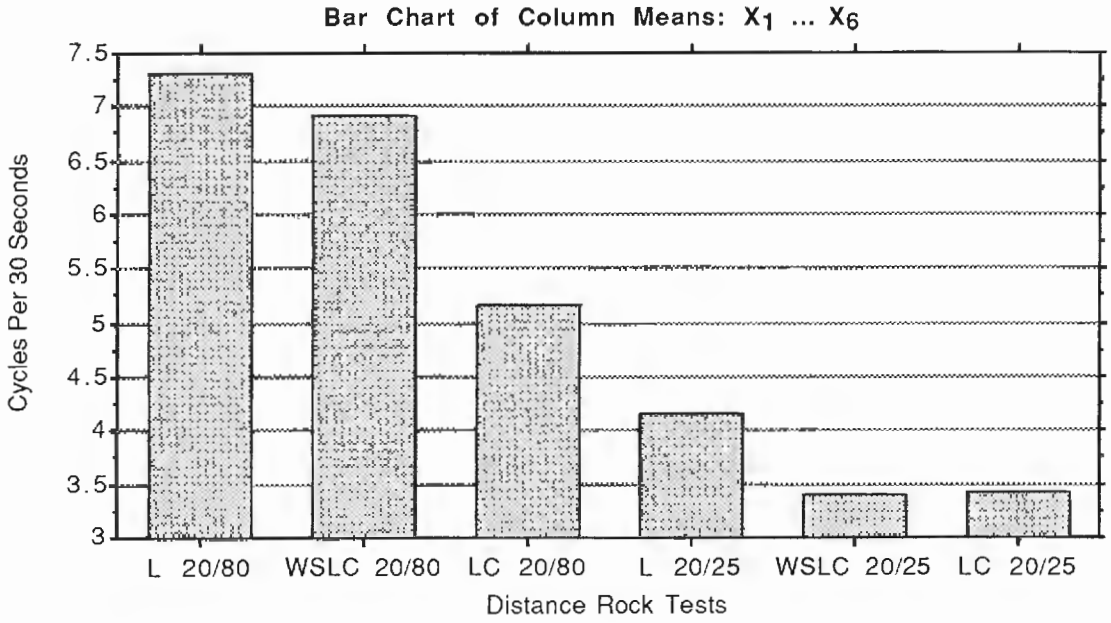
APPENDIX D: Comparison of First Graders' Performance Means

The bar chart has

a horizontal axis of distance rock tests, and

a vertical axis of cycles per thirty seconds.

Comparison of First Graders' Performance Means



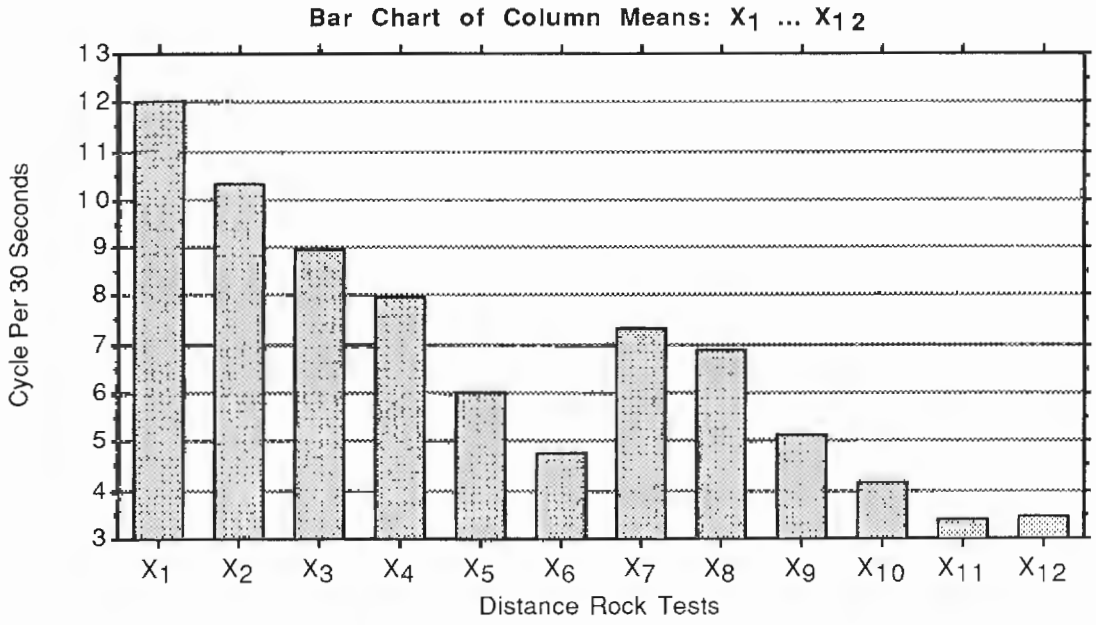
APPENDIX E: Comparison of Fourth and First Graders' Performance Means

The bar chart has

a horizontal axis of distance rock tests, and

a vertical axis of cycles per thirty seconds.

Comparison of Fourth and First Graders' Performance Means



APPENDIX F: Correlation Matrix of Fourth Graders ' Distance Rock Test

Correlation Matrix of First Graders' Distance Rock Test

Correlation Matrix of Fourth Graders' Distance Rock Tests

Correlation Matrix for Variables: X_1 ... X_6

	L 20/80	WSLC 2...	LC 20/80	L 20/25	WSLC 2...	LC 20/25
L 20/80	1					
WSLC 20/80	.564	1				
LC 20/80	.481	.417	1			
L 20/25	.316	.314	.309	1		
WSLC 20/25	.537	.471	.565	.424	1	
LC 20/25	.126	.132	.093	.347	.178	1

Correlation Matrix of First Graders' Distance Rock Tests

Correlation Matrix for Variables: X_1 ... X_6

	L 20/80	WSLC 2...	LC 20/80	L 20/25	WSLC 2...	LC 20/25
L 20/80	1					
WSLC 20/80	.664	1				
LC 20/80	.546	.486	1			
L 20/25	.727	.606	.275	1		
WSLC 20/25	.391	.418	.185	.313	1	
LC 20/25	.27	.131	.311	-.099	.461	1