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Distance rock and eye trac correlations

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Distance rock and eye trac correlations

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DISTANCE ROCK AND

EYE TRAC CORRELATIONS

by

Kathy Ishimoto and Barbara Jung

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TABLE OF CONTENTS

LIST OF TABLES

PROBLEM

This research was designed as an exploratory study
to determine if eye movement recordings under prose para-
graph reading are statistically related to near-far letter
reading on the Distance Rock Test. The investigation was
designed to hold comprehension constant in paragraph reading
and compares two measures of sequential near-far letter
reading to eye movement recordings of number of fixations,
regressions, duration of fixations, span, and words/minute.

The experimental basis for the inquiry comes from an
earlier study by Gilbert[1] who showed that eye movements
under digit reading and prose reading were positively
related from the first to the twelfth grade.

LITERATURE REVIEW

A Distance Rock Test (D_{rk}) measures the response
time in cycles/minute of the visual system as it shifts
from distance to near and back to distance while making a
discriminatory response to a specific criterion. Many
variables are involved in this response. Known variables
include static refraction, accommodation, vergences
responses, target conditions, instructions, etc.

Stevens[2] determined that angular letter size and
letter separation affected D_{rk} response times. Haynes[3]
has reported that the mean and median response times were
significantly longer for the 20/25 letters than for the
20/80 sized letters. Average response times for the 20/80
letters was 37.8 cyc/min and for the 20/25 letters was 25.2
cyc/min. Letter spacing also affected response times with
averages of 47.8 cyc/min for 20/80 letters with 5' letter
separation and 33.3 cyc/min for 1' separation of 26 and 20
cyc/min respectively.

Mann, Martin and Moore[4] found response times on the
D_{rk} to increase with grade level from the first through
sixth grade. Grade level norms were developed for these
grades by Haynes, Siestra and Stoppel[5]. The referral rate
using the D_{rk} versus the Modified Clinical Test (MCT) was
compared. Ten percent more children were found by the D_{rk}
referral criteria than by the MCT criteria.

A practice effect was reported by Haynes and McWilliams[6].
The response times improved from the initial to final
training sessions.

2

The effects of spheres and prisms on the response times of the D_{rk} was determined by Haynes, Hartman, Sommers, and Wanny[7]. Base out and base in prisms significantly reduced the response time for both 20/80 and 20/25 letters. No significant differences were found for +.50 and -.50 on 20/80 targets. A +.50 sphere reduced the response time on 20/25 letters while the -.50 sphere on 20/25 letters was found at the .06 level rather than the .05 criteria level. The bifocal add equal to the average of the low neutral dynamic retinoscopy and binocular cross cylinder showed no change while an add of twice that amount reduced performance.

Response times and visual discrimination are affected by oculomotor functions. According to the results of H.L. Poynter[8] when the factors of language difficulty, the structure of language and verbal intelligence are taken into account, a positive relationship between oculomotor functions and reading ability remained. He stated that according to his results a positive relationship of moderate magnitude (12-21%) existed between oculomotor function responses to basic stimuli and reading ability in intermediate age levels.

Accommodation is an influential factor in the response time of the D_{rk} and on eye movements during letter reading. Kirchoff's[9] study indicated that the time to accommodate increased as the amplitude of accommodation decreased. With incomplete use of the accommodative amplitude, speed of accommodation increased. Accommodation speed for the

change from far to near was on the average fifteen percent

less than for near to far changes. With muscle fatique,

accommodative time increased thirty six percent for far

to near changes while no effect resulted for near to far

changes. Kirchoff also pointed out that accommodation is

not constant but subject to will and concentration. Merrill[10]

determined that subjects underaccommodated for 2.0 diopter

stimulus while over-accommodated for zero stimulus. In

addition, innervation to accommodation and convergence

occurred simultaneously with accommodation lagging behind

convergence by .1 second. Ittelson[11] found that perceptual

factors also influenced oculomotor functions. His study

revealed that accommodation and convergence varied in the

direction of apparant distance. Nedrow[12] extended the

effects of accommodation to reading ability. He found that

accommodative performance was less skilled in poor readers

as compared to good readers.

Letter discriminations is a major factor in the D_{rk}

and prose reading and is the mode through which the eye

track recordings are made. Lahey and McNeis[13] hypothesized

from their study that good letter discriminations act as a

basis and might indirectly facilitate the aquisition of all

other skills which are hierarchically dependent upon it.

In a study conducted by Lahey and Lefton[14], visual discrim-

ination of matching letters was correlated with reading.

While performing matching tasks, the percentage of errors

for good and poor readers of one grade level was a function

of the number of letters in the stimuli. Poor readers

were found to make more errors than good readers on longer items. The effects of letter spacing on visual discrimination was also significant. All subjects made significantly fewer errors on widely spaced items thatn normally spaced item. These results suggest that errors of visual discrimination may play an important role in reading problems during elementary school.

In another study, Lefton, Lahey and Stagg[15] investigated why poor readers made more errors than good readers. Their results revealed that younger children made more fixations of longer duration than adults. Their patterns of fixations were more conservative in strategies than adults. Reading disabled children made fixations and durations comparable to their age group but their sequence of fixations were neither conservative or systematic. These results suggest that reading disabled children are not more likely to fail to discriminate letter shapes than normals or fail in any other task not requiring sustained attention. Any problems the children were having were probably due to their unsystematic strategy in examining letters and their failure to use a positive systematic sequential examination under sustained attention.

Biemiller[16] found high relationships between letter, word and text times. Older children and adults have faster rates for reading unrelated letters, unrelated words and simple texts. He found an underlying ability to identify printed itens quickly, irrespectively of context and ortho-

graphic information. This ability improved with age. Significant correlations between the time needed to identify letters, numbers and pictures in the same print size were found by the author and his students. Biemiller hypothesized that the time difference in good and poor readers was due to the time needed to process letter features. This increase in time could be due to "processing more features rather than feature processing time." This would affect the D_{rk} by causing an increased response time and longer fixations on the eye track recordings.

Gilbert[17] found that digit reading across a page and prose reading were closely related. He found that no one in the bottom quartile in digit reading was in the top quartile of prose reading and vice versa.

EXPERIMENTAL DESIGN

Subject Selection

This exploratory study was limited to college students. Fifty
eight volunteers from the first, second and fourth year optometry classes
at Pacific University College of Optometry were chosen to participate in
this study. Optometry students were selected because of the rigid en-
trance requirements which should reasonable control IQ and preclude
serious forms of reading disabilities. Comprehension and vocabulary
variables were controlled by the EDL standardized test cards. Grade
school children were not included in this study as behaviors measured
may be age related and correlations may vary with age and school experi-
ences. A minimum number of fifty volunteer subjects was decided upon
for statistical purposes.

Selection Criteria

Volunteer subjects were selected for this study based on the
following criteria:

1. Visual acuity equal or better than 20/25 at 6 meters and
   16 inches in each eye

2. Cover Test: to preclude any evidence of strabismus

3. Case History: included the following questions
   (1) Do you have difficulty seeing at near?
   (2) Do you have difficulty seeing at far?
   (3) Do you have difficulty seeing from near to far or far
       to near?
   (4) If you answered yes to questions (1), (2), or (3),
       have you received any treatment and if so, what type?
   (5) Are you currently wearing a prescription?

4. No evidence of ocular pathology, injury or surgery in the
   last two years

Eye Movement Recordings (EMR)

The Eye Trac recording was taken of each subject. The reading material consisted of twelve lines of prose pertaining to a specific topic. The card used was the high school/adult reading card. The first and last lines were not included in the calculations. Therefore, the measurements were based on the recordings of the middle ten lines for a total of 100 words. A minimal reading performance of eighty percent comprehension or greater was set. This was determined by asking the subject ten questions about the reading material after they had finished. If they did not achieve the required eighty percent with the first paragraph, a second recording was taken with the junior high #5 card.

For each eye the following quantitative observations were determined:

#F = number of fixations per 100 words

= actual count of all fixations less return sweeps and the first and last lines of reading test recordings

#RG = number of regressions per 100 words

= actual count of all regressions less return sweeps and the first and last lines of reading test recordings

S = mean word span per 100 words

$$= \frac{\text{number of words read}}{\text{number of fixations}}$$

S-RG $$= \frac{\text{number of words read}}{\text{fixations-regressions}}$$

D = mean duration of fixation

$$= \frac{\text{total reading time in seconds}}{\text{number of fixations}}$$

words/min $$= 100 \text{ words X} \frac{\text{elapsed time (sec)}}{60 \text{ sec}}$$

Statistical Analysis

For each set of observations and quantitative evaluation of eye movements, the mean, median, standard deviation, mode and frequency distribution were determined. Each subject's raw score were converted to a standard score or z-score by:

$$z\text{-score} = \frac{\text{subject's score} - \text{sample mean}}{\text{standard deviation}}$$

Pearson's Product Moment Correlation Coefficient was used to correlate the following factors:

Instrument and interpreter reliability on the EMR were tested by #fixations, #regressions, span, span-regressions, duration, and words/min of the right eye as compared to the left eye

#Fixations to words/min

#Fixations to Duration

#Fixations to #Regressions

#Regressions to words/min

Span-Regressions to Duration

Distance Rock Test (D_{rk})

The target for the D_{rk} consisted of rows of ten Sloan optotype capital letters. Targets consisted of six alternate horizontal rows of 20/80 and 20/25 acuity letters for near and far. Test distances were set at 6 meters and 16 inches. Room illumination was set at

Subjects were instructed to read aloud the 20/80 letters al-ternately from the far target to the near target as quickly and accurately as possible. This was repeated for the 20/25 letters. Accuracy was recorded in terms of the number of letters miss-named, ommitted, read out of sequence or repeated.

From the data obtained, the following calculations were determined:

$$\text{alternations/minute} = \frac{\text{number of letters read} - 1}{\text{elapsed time in minutes}}$$

$$\text{cycles/minute} = \frac{\text{alternations/minute}}{2}$$

$$\text{Average response time/letter} = \frac{\text{elapsed time in seconds}}{\text{number of letters read}}$$

$$\text{Errors/minute} = \frac{\Sigma \text{ of all errors}}{\text{elapsed time in minutes}}$$

$$\text{Errors/letters read} = \frac{\Sigma \text{ of all errors}}{\text{number of letters read}}$$

$$\text{Error adjusted score (cyc/min)} = \frac{\text{alternations} - \text{errors} \div 2}{\text{elapsed time in min}}$$

For each calculation, the mean, standard deviation, mode and frequency distribution were determined. The measurements were converted to standard scores or z-scores.

Pearsons' Product Moment Correlation Coefficient was used to correlate the follwoing factors:

Cycles/minute to Error Adjucted Score

#Errors/letter read to Error Adjusted Score

Average Response Time/letter to Errors/letters read

Correlations

Pearsons' Product Moment Correlation Coefficent was used to correlate the two tests in the following relationships:

#Errors/letter read to #Regressions

#Regressions to Error Adjusted Score

Words/min to Error Adjusted Score

Errors/min to #Regressions

#Fixations to Cycles/minute

#Fixations to Error Adjusted Score

RESULTS

Fifty eight volunteer optometry students meeting selection criteria served as subjects. The results from the D_{rk} test, the EMR and correlations between the two tests were analyzed spearately. In each case where a statistically confidence level was required, we arbitrarily chose the 5% level (Γ = .05) to reject the null hypothesis. Thus, in the tables of correlation which follow, any correlation $\leq \pm .27$ was considered as a chance occurance.

$$\Gamma \text{ (if } r=0\text{)} \quad \frac{1}{\sqrt{N-1}} \quad = \quad \frac{1}{\sqrt{58-1}} \quad = \quad .134$$

for 5% level then .134 X 2 = .27

Appendixes A and B contain eye trac measurements for the right and left eyes respectively. Distance Rock measurements are found in Appendix C.

Frequency distributions for the following factors are shown in Tables I through V (see pages 1 to 11 for discription of how the data listed were calculated).

I. Right Eye: #Fixations, #Regressions, Span Duration, Span-Regressions, words/minute

II. Errors/letter read for 20/80 and 20/25 letters

III. Cycles/minute for 20/80 and 20/25 letters

IV. Total errors for 20/80 and 20/25 letters

V. Error adjusted score for 20/80 and 20/25 letters

The mode, median and range of errors for the fifty eight college subjects are shown immediately below each distribution.

12

Table I

Frequency Distributions

Right Eye

<u># Fixations</u>

z-SCORE	Number (X=1)
-1.99 - -1.50	XXX
-1.49 - -1.00	XXXXXX
- .99 - - .50	XXXXXXXXX
- .49 - 0.00	XXXXXXXXXX
+ .01 - + .50	XXXXXXXXXXXXX
+ .51 - +1.00	XXXXXXXXX
+1.01 - +1.50	XXXX
+1.51 - +2.00	XX
+2.01 - +2.50	XX
>+2.51	

Mode +..01 - +.50
Median + .325
Range   -1.84 - +2.49

<u># Regressions</u>

z-SCORE	Number (X=1)
-1.99 - -1.50	XX
-1.49 - -1.00	XXXXXX
- .99 - - .50	XXXXXXXXXXXXX
- .49 - 0.00	XXXXXXXXX
+ .01 - + .50	XXXXXXXXXXXX
+ .51 - +1.00	XXXXXXX
+1.01 - +1.50	XXXXX
+1.51 - +2.00	X
+2.01 - +2.50	XX
>+2.51	X

Mode - .99 - - .50
Median + .66
Range   -1.67 - +2.99

<u>Span</u>

z-SCORE	Number (X=1)
<-3.00	X
-2.99 - -2.50	
-2.49 - -2.00	
-1.99 - -1.50	XX
-1.49 - -1.00	XXXXX
- .99 - - .50	XXXXXXXXX
- .49 - 0.00	XXXXXXXXXXXXXXXX
+ .01 - + .50	XXXXXXXXXXX
+ .51 - +1.00	XXXXX
+1.01 - +1.50	X
+1.51 - +2.00	XXXXX
+2.01 - +2.50	
>+2.51	XX

Mode - .49 - 0.00
Median - .20
Range   -3.12 - +2.72

<u>Duration (sec/F)</u>

z-SCORE	Number (X=1)
<-3.00	
-2.99 - -2.50	
-2.49 - -2.00	
-1.99 - -1.50	XX
-1.49 - -1.00	XXXXXXX
- .99 - - .50	XXXXXXXXXXXXX
- .49 - 0.00	XXXXXXXX
+ .01 - + .50	XXXXXXXXXXXX
+..51 - +1.00	XXXXX
+1.01 - +1.50	XXXXXX
+1.51 - +2.00	XXXX
+2.01 - +2.50	
>+2.51	X

Mode - .99 - - .49
Median + .46
Range   -1.62 - +2.54

Span-Regressions

z-SCORE	Number (X=1)
-2.49 - -2.00	XX
-1.99 - -1.50	XXX
-1.49 - -1.00	XXXXXXXX
- .99 - - .50	XXXXXXXXXXXXX
- .49 - 0.00	XXXXXXXX
+ .01 - + .50	XXXXXXX
+ .51 - +1.00	XXXXXXX
+1.01 - +1.50	XXX
+1.51 - +2.00	XXXX
+2.01 - +2.50	X
>+2.51	

Mode - .99 - - .50
Median - .13
Range -2.29 - +2.03

Words/Minute

z-SCORE	Number (X=1)
-2.49 - -2.00	
-1.99 - -1.50	XX
-1.49 - -1.00	XXXXXXX
- .99 - - .50	XXXXXXXXXX
- .49 - 0.00	XXXXXXXXXXXX
+ .01 - + .50	XXXXXXXX
+ .51 - +1.00	XXXXXXXXXXX
+1.01 - +1.50	XXXX
+1.51 - +2.00	XX
+2.01 - +2.50	X
>+2.51	X

Mode - .49 - 0.00
Median + .145
Range -1.74 - +2.03

Table II

Frequency Distributions

Errors/letter Read

20/80 Letters

z-SCORE	Number (X=1)
- .99 - - .50	XXXXXXXXXXXXXXXXXXXXXXX
- .49 - 0.00	XXXXXXXXX
+ .01 - + .50	XXXX
+ .51 - +1.00	XXXXXXXXXXXXX
+1.01 - +1.50	XXXXXX
+1.51 - +2.00	X
+2.01 - +2.50	X
+2.51 - +3.00	
+3.01 - +3.50	X

Mode - .99 - - .50
Median + .475
Range - .95 - +3.483

20/25 Letters

z-SCORE	Number (X=1)
-1.49 - -1.00	XXXXXXX
- .99 - - .50	XXXXXXX
- .49 - 0.00	XXXXXXXXXXXXXXXXXXXXX
+ .01 - + .50	XXXXXXX
+ .51 - +1.00	XXXXXXXX
+1.01 - +1.50	XXX
+1.51 - +2.00	XX
+2.01 - +2.50	XX
+2.51 - +3.00	
+3.01 - +3.50	
+3.51 - +4.00	X

Mode - .49 - 0.00
Median +1.208
Range -1.256 - +3.672

Table III

Frequency Distributions

Cycles/Minute

20/80 Letters

z-SCORE	Number (X=1)
-2.49 - -2.00	
-1.99 - -1.50	X
-1.49 - -1.00	XXXXXXXXX
- .99 - - .50	XXXXXXXXXXXX
- .49 - 0.00	XXXXXX
+ .01 - + .50	XXXXXXXXXXXX
+ .51 - +1.00	XXXXXXXX
+1.01 - +1.50	X
+1.51 - +2.00	
+2.01 - +2.50	

Mode - .99 - - .50
Median - .935
Range -1.99 - +3.11

20/25 Letters

z-SCORE	Number (X=1)
-2.49 - -2.00	X
-1.99 - -1.50	XXX
-1.49 - -1.00	XXXXXXXXX
- .99 - - .50	XXXXXX
- .49 - 0.00	XXXXXXXXXXXX
+ .01 - + .50	XXXXXXX
+ .51 - +1.00	XXXXXXXXXXX
+1.01 - +1.50	XXX
+1.51 - +2.00	XX
+2.01 - +2.50	XX

Mode - .49 - 0.00
Median + .215
Range -2.00 - +2.43

Table IV   17

Frequency Distributions

Total Errors

20/80 Letters

z-SCORE	Number (X=1)
− .99 − − .50	XXXXXXXXXXXXXXXXXXXXXXXX
− .49 − 0.00	XXXXXXXX
+ .01 − + .50	XXXXX
+ .51 − +1.00	XXXXXXXXXXXXX
+1.01 − +1.50	XXXXX
+1.51 − +2.00	X
+2.01 − +2.50	X
>+2.51	X

Mode   − .99 − − .50
Median +1.265
Range   − .92 − +3.45

20/25 LETTERS

z-SCORE	Number (X=1)
−1.49 − −1.00	XXXXXXX
− .99 − − .50	XXXXXXXXXXXXX
− .49 − 0.00	XXXXXXXXXXXXX
+ .01 − + .50	XXXXXXX
+ .51 − +1.00	XXXXXXXX
+1.01 − +1.50	XXX
+1.51 − +2.00	XX
+2.01 − +2.50	XX
>+2.51	X

Mode   − .99 − 0.00
Median +1.28
Range   − 1.19 − +3.75

Table V

Frequency Distributions

Error Adjusted Score

20/80 Letters

z-SCORE	Number (X=1)
-1.99 - -1.50	X
-1.49 - -1.00	XXXXXXX
- .99 - - .50	XXXXXXXXXX
- .49 - 0.00	XXXXXXXXXXX
+ .01 - + .50	XXXXXXXXXXXXX
+ .51 - +1.00	XXXXX
+1.01 - +1.50	XX
+1.51 - +2.00	XXXXXX
+2.01 - +2.00	XX

Mode + .91 - + .50
Median   .285
Range -1.68 - +2.25

20/25 Letters

z-SCORE	Number (X=1)
⟨-2.50	X
-2.49 - -2.00	
-1.99 - -1.50	XXX
-1.49 - -1.00	XXXXX
- .99 - - .50	XXXXXXXX
- .49 - 0.00	XXXXXXXXXXX
+ .01 - + .50	XXXXXXXXX
+ .51 - +1.00	XXXXXXXXXXX
+1.01 - +1.50	XXXXX
+1.51 - +2.00	XXX
+2.01 - +2.50	

Mode - .49 - 0.00
Median - .355
Range -2.57 - +1.86

Correlations between the several D_{rk} test results are shown in Table VI. The correlation between various D_{rk} measurements were found to be significant for both the 20/80 and 20/25 letters. The error adjusted score correlated with the cycle/minute at the .8 level. This high correlation indicates that the subjects tended to make more errors as the rate increased. The errors/letter read had a significantly negative correlation ($r= -.31$ for 20/80 letters and $r= -.50$ for 20/25 letters) to the error adjusted score. As the subjects increased in the rate at which they alternately looked from near to far, the frequency of errors relative to each letter read decreased. Therefore, speed and accuracy increased simultaneously. The average response time/letter was not correlated to the errors/letter.

Table VI

Correlations for Distance Rock Measurements

CORRELATIONS	r
Error Adjusted Score to Cycle/Minute:	
20/80 Letters	.784376
20/25 Letters	.818695
Errors/letters read to Error Adjusted Score:	
20/80 Letters	-.314638
20/25 Letters	-.498413
Average Response Time/letter to Errors/letter read:	
20/80 Letters	.138510
20/25 Letters	.157209

Table VII

Correlations for Eye Trac Measurements

CORRELATIONS	r
Right to Left Eye:	
#Fixations	.99
#Regressions	.96
Span	.95
Span-Regressions	.89
Duration	.95
Words/minute	.99
#Fixations to Words/min:	
Right eye	-.87
Left eye	-.87
#Fixations to Duration:	
Right eye	-.04
Left eye	-.03
#Fixations to #Regressions:	
Right eye	.75
Left eye	.77
#Regressions to words/minute:	
Right eye	-.65
Left eye	-.63
Span-Regression to Duration:	
Right eye	.09
Left eye	.02

The correlations between the right and left eyes in Table VII were run as an internal check of the reliability of the interpreter and the recording of the Eye Trac instrument. All the correlations were high, ranging from .89 to .99. From these correlations it may be assumed that the interpreter and the recordings were quite reliable.

Three different relationships were found from correlating the six variables of the EMR. The only positive correlation was between the number of fixations and the number of regressions. This was expected because the regressions are counted as part of the number of fixations. Therefore, the greater the number of regressions, the greater the number of fixations.

There were two negative correlations. They were the number of fixations to the words per minute and the number of regressions to words per minute. There was a very high negative correlation ($r= -.8$) between the number of fixations and the words per minute read. This shows that the subjects who read a greater number of words in one minute with comprehension controlled made fewer fixations. The correlation between the number of regressions and words per minute read was relatively high ($r= -.6$). With a greater number of regressions there were fewer words per minute read.

When comparing the number of fixations to the duration (seconds/fixation) there was no correlation at all. These may be considered independent variables. The word span minus regressions (S-Rg) was also an independent

variable when compared to the duration.

When comparing distance rock to eye trac measure-
ments (Table VIII), no overall significant correlations were
discovered. This suggests that the distance rock test and
eye trac measure different types of reading.

The relationships of #fixations with cycle/minute
and error adjusted score were found to be insignificant
and thus were independent variables. Since eye trac and
distance rock test involved different modes of reading,
this insignificant correlation is understandable.

Letter size becomes a loading factor when determining
relationships between #regressions and words/minute to
distance rock measurements. #Regressions to errors/letter
read, #regressions to errors/minute, #regressions to error
adjusted score and words/minute to error adjusted score
were found to be slightly, but not significantly correlated
for the 20/80 letters and to have no relationship for the
20/25 letters. According to our statistical confidence
level of 5%, the correlations found for the 20/80 letters
were due to chance.

Visual case history findings were not correlated to
D_{rk} or EMR.

23

Table VIII

Correlations Between Eye Trac
and Distance Rock Measurements

CORRELATIONS	r
#Regressions to Errors/letter read:	
Right eye to 20/80 letters	.292287
Right eye to 20/25 letters	.005354
Left eye to 20/80 letters	.242119
Left eye to 20/25 letters	-.031186
#Regressions to Error Adjusted Score:	
Right eye to 20/80 letters	-.179209
Right eye to 20/25 letters	.002232
Left eye to 20/80 letters	-.218529
Left eye to 20/25 letters	-.028462
Words/minute to Error Adjusted Score:	
Right eye to 20/80 letters	.092793
Right eye to 20/25 letters	.051748
Left eye to 20/80 letters	.126012
Left eye to 20/25 letters	.072688
Errors/minute to #Regressions:	
Right eye to 20/80 letters	.211252
Right eye to 20/25 letters	.041873
Left eye to 20/80 letters	.164467
Left eye to 20/25 letters	-.010862
#Fixations to cycles/minute:	
Right eye to 20/80 letters	.081126
Right eye to 20/25 letters	-.042333
Left eye to 20/80 letters	-.026162
Left eye to 20/25 letters	-.098817
#Fixations to Error Adjusted Score:	
Right eye to 20/80 letters	-.167201
Right eye to 20/25 letters	-.018231
Left eye to 20/80 letters	-.203585
Left eye to 20/25 letters	.000219

DISCUSSION

This study is the first to look into the relationship of eye movements in the distance rock test and eye movement recordings.

Near-far letter reading under D_{rk} test conditions shows no significant relationships to eye movement measurements as recorded under paragraph reading conditions for college students from the College of Optometry. These results suggest that the various eye movement muscle systems are highly dependent on the type of reading tasks. Increased regressions under prose reading is not predictable under near-far letter reading under 20/80 or 20/25 acuity conditions. A significant relationship at the elementary school level has not been ruled out because no grade school children were sampled.

This preliminary investigation concluded that there is no significant relationship between successive near to far single letter reading and prose reading. From these findings it has been determined that the distance rock cannot be utilized as a satisfactory screening device for eye movements used in reading among college students.

SUMMARY

The distance rock test and eye trac recordings were administered to fifty eight volunteer subjects from the first, second and fourth year classes at Pacific University College of Optometry. Findings from both tests were correlated using the Pearson r to determine if prose reading was related to the near to far letter reading in the distance rock test. Our findings indicated that these tests measured different types of reading and were not significantly correlated. Therefore, the distance rock test cannot be a valid test to determine the quality of eye movements during prose reading.

FOOTNOTES

1. Gilbert, L.C., "Functional Motor Efficiency of the eyes and its Relationship to Reading," <u>Publications in Education</u>, 11(7):159-232, 1953.

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EYE TRAC MEASUREMENTS - RIGHT EYE

SUBJECT	NO. OF FIXATIONS		NO. OF REGRESSIONS		SPAN	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
1 BH	45	-1.843	0	-1.673	2.22	2.724
2 JR	70	- .584	14	- .079	1.43	.380
3 AA	82	.021	20	.604	1.22	- .243
4 SC	83	.072	19	.490	1.20	- .303
5 GY	93	.576	19	.490	1.08	- .659
6 DH	51	-1.541	0	-1.673	1.96	1.953
7 MB	70	- .584	16	.149	1.42	.350
8 MR	86	.223	21	.718	1.16	- .421
9 GM	---	----	--	----	-----	----
10 TG	77	- .231	23	.945	1.30	- .006
11 GS	81	- .290	7	- .876	1.23	- .214
12 TD	45	-1.844	3	-1.332	2.22	3.724
13 HW	88	.324	20	.604	1.14	- .481
14 MB	74	- .382	10	- .535	1.35	.142
15 MC	119	1.887	26	1.287	.84	-1.371
16 KH	129	2.391	41	2.995	.77	-1.564
17 DC	54	-1.390	8	- .762	1.85	1.626
18 BP	98	.828	11	- .421	1.02	- .837
19 CS	55	-1.340	7	- .876	1.82	1.537
20 DJ	88	.324	4	-1.218	1.14	- .481
21 PT	99	.878	31	1.856	1.01	- .866
22 RN	131	2.492	33	2.084	.76	-1.599
23 DS	95	.677	19	.490	1.05	- .748
24 DF	71	- .533	8	- .762	1.41	.320
25 JI	108	1.332	36	2.426	.93	-1.116
26 GK	75	- .332	13	- .193	1.33	.083
27 DK	85	.173	18	.376	1.18	- .362
28 LL	104	1.139	22	.831	.96	-1.009
29 FM	80	- .079	18	.376	1.25	- .154
30 JH	96	.727	18	.376	1.04	-3.122
31 LM	64	- .886	10	- .535	1.56	.766
32 WV	91	.475	17	.262	1.10	- .599
33 KW	105	1.181	17	.262	.95	-1.039
34 TB	86	.223	21	.718	1.16	- .421
35 EM	72	- .483	12	- .306	1.39	.261
36 DM	89	.374	13	- .193	1.12	- .540
37 MJ	62	- .987	13	- .193	1.61	.914
38 MB	84	.122	12	- .307	1.19	- .332
39 DT	98	.828	24	1.059	1.02	- .837
40 JS	86	.223	10	- .535	1.16	- .421
41 DB	117	1.786	16	.149	.85	-1.326
42 DF	75	- .332	4	-1.218	1.33	.083
43 DM	75	- .332	8	- .762	1.33	.083
44 RF	102	1.030	24	1.059	.98	- .955
45 BP	68	- .684	5	-1.104	1.47	.499

SUBJECT	NO. OF FIXATIONS		NO. OF REGRESSIONS		SPAN	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
46 RN	68	− .684	15	.035	1.47	.499
47 DS	75	− .331	4	−1.218	1.33	.083
48 BP	---	----	---	----	----	---
49 JP	82	.021	26	1.287	1.22	− .243
50 RB	62	− .987	8	− .762	1.61	.914
51 MC	85	.172	9	− .648	1.18	− .362
52 RR	86	.223	3	−1.331	1.16	− .421
53 SM	55	−1.340	8	− .762	1.82	1.537
54 TS	71	− .533	13	− .193	1.41	.320
55 PL	52	−1.491	6	− .990	1.92	1.833
56 LK	79	− .130	12	− .307	1.27	− .095
57 KE	---	. ---	---	. ---	----	---
58 OC	63	− .936	19	.490	1.59	.855
59 IK	101	.979	23	.946	.99	− .926
60 SI	61	−1.037	8	− .762	1.64	1.003
61 DT	56	−1.289	5	−1.104	1.79	1.448
MEAN	81.57		14.70		1.30	
SD	19.84		8.78		.34	

SUBJECT	SPAN-REGRESSIONS		DURATION (SEC/F)		WORDS/MINUTE	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
1 BH	2.22	1.887	.275	− .974	484	3.370
1 JR	1.79	− .396	.274	−1.000	313	.875
3 AA	1.61	−1.003	.287	− .667	255	.029
4 SC	1.56	−1.061	.251	−1.590	288	.511
5 GY	1.35	−1.408	.284	− .744	227	− .379
6 DH	1.96	−1.136	.320	.179	368	1.678
7 MB	1.79	− .425	.329	.410	260	.102
8 MR	1.54	−1.176	.279	− .872	251	− .029
9 GM	-----	-----	----	----	----	----
10 TG	1.85	− .772	.323	.256	241	− .175
11 SG	1.35	− .974	.297	− .410	249	− .058
12 TD	2.38	1.887	.380	1.718	351	1.430
13 HW	1.47	−1.234	.298	− .385	229	− .350
14 MB	1.56	− .627	.312	− .026	260	.102
15 MC	1.08	−2.101	.326	.333	155	−1.430
16 DJ	1.14	−2.289	.318	.128	146	−1.561
17 DC	2.17	.818	.331	.462	336	1.211
18 BP	1.15	−1.581	.382	1.769	160	−1.357
19 CS	2.08	.731	.369	1.436	296	.627
20 DJ	1.19	−1.090	.311	− .051	219	− .496
21 PT	1.47	− .280	.355	1.077	171	−1.197
22 RN	1.02	−1.581	.343	.769	134	−1.736
23 DS	1.32	− .714	.367	1.385	172	−1.182
24 DF	1.59	.066	.313	0.000	270	.248
25 JI	1.39	− .511	.256	−1.462	217	−.525
26 GK	1.61	.124	.289	− .615	276	.335
27 DK	1.49	− .223	.412	2.538	171	−1.197
28 LL	1.22	−1.003	.345	.821	167	−1.255
29 FM	1.61	.124	.377	1.641	199	− .788
30 JH	1.28	− .829	.331	.462	189	− .934
31 LM	1.85	.818	.317	.103	296	.627
32 WV	1.35	− .627	.340	.692	194	− .861
33 KW	1.14	−1.234	.283	− .769	202	− .744
34 TB	1.59	.066	.272	−1.051	256	.044
35 EM	1.67	.297	.365	1.333	288	.511
36 DM	1.31	− .743	.301	− .308	224	− .423
37 MJ	2.04	1.367	.290	− .590	333	1.167
38 MB	1.39	− .512	.295	− .462	242	−.161
39 DT	1.35	− .627	.263	−1.282	233	− .292
40 JS	1.32	− .714	.370	1.462	189	− .934
41 DB	.99	−1.668	.315	.051	163	−1.313
42 DF	1.41	− .425	.285	− .718	281	.408
43 DM	1.49	− .223	.272	−1.051	294	.598
44 RF	1.28	− .829	.285	− .718	207	− .671
45 BP	1.59	.066	.286	− .692	307	.788
46 RN	1.89	.934	.362	1.256	244	− .131
47 DS	1.41	− .454	.257	−1.436	311	.846
48 BP	-----	----	----	----	----	----
49 JP	1.79	.645	.329	.410	244	− .131

SUBJECT	SPAN-REGRESSIONS		DURATION (SEC/F)		WORDS/MINUTE	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
50 RB	1.85	.818	.282	- .795	343	1.313
51 MC	1.32	- .714	.323	.256	219	- .496
52 RR	1.20	-1.061	.280	- .846	249	- .058
53 SM	2.13	1.627	.375	1.590	291	.554
54 TS	1.72	.442	.269	-1.128	314	.890
55 PL	2.17	1.742	.294	- .487	392	2.028
56 LK	1.49	- .223	.323	.256	235	- .263
57 KE	------	----	---	---	---	---
58 OC	2.27	2.032	.250	-1.615	381	1.868
59 IK	1.28	- .829	.272	-1.051	218	- .511
60 SI	1.89	.934	.344	.795	286	.481
61 DT	1.96	1.136	.339	.667	316	.919
MEAN	1.567		.313		253.0	
SD	.346		.039		68.5	

EYE TRAC MEASUREMENTS - LEFT EYE

SUBJECT	NO. OF FIXATIONS		NO. OF REGRESSIONS		SPAN	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
1 BH	47	-1.732	2	-1.400	2.13	2.485
2 JR	69	- .625	15	.037	1.45	.437
3 AA	82	.021	20	.591	1.22	- .256
4 SC	81	- .028	17	.259	1.23	- .226
5 SY	93	.583	18	.369	1.08	- .678
6 DH	52	-1.481	0	-1.622	1.92	1.852
7 MB	75	- .323	15	.037	1.33	.075
8 MR	86	.230	21	.701	1.16	- .437
9 GM	----	----	----	----	----	----
10 TG	76	- .273	23	.922	1.32	.045
11 GS	81	- .021	7	- .847	1.23	- .226
12 TD	46	-1.783	3	-1.290	2.17	2.605
13 HW	87	.281	21	.701	1.15	- .467
14 MB	74	- .373	10	- .516	1.35	.136
15 MC	117	1.790	27	1.365	.86	-1.355
16 KH	130	2.445	41	2.913	.77	-1.614
17 DC	50	-1.581	4	-1.179	2.00	2.093
18 BP	96	.734	9	- .626	1.04	- .798
19 CS	55	-1.330	7	- .847	1.82	1.551
20 DJ	88	.331	5	-1.069	1.14	- .497
21 PT	96	.734	30	1.697	1.04	- .798
22 RN	135	2.696	36	2.360	.74	-1.699
23 DS	97	.784	20	.591	1.03	- .828
24 DF	71	- .525	7	- .847	1.41	.316
25 JI	104	1.136	34	2.139	.96	-1.033
26 GK	77	- .223	13	- .184	1.29	- .045
27 DK	87	.281	20	.591	1.15	- .467
28 LL	104	1.136	22	.812	.96	-1.033
29 FM	75	- .323	9	- .626	1.33	.075
30 JH	96	.734	20	.591	1.04	- .798
31 LM	64	- .877	10	- .516	1.56	.768
32 VW	95	.683	18	.369	1.05	- .768
33 KW	106	1.237	22	.812	.94	-1.090
34 TB	78	- .172	13	- .184	1.28	- .075
35 EM	73	- .424	14	- .073	1.37	.196
36 DM	89	.381	9	- .626	1.22	- .256
37 MJ	62	- .978	12	- .294	1.61	.919
38 MB	85	.180	11	- .405	1.18	- .377
39 DT	97	.784	24	1.033	1.03	- .828
40 JS	89	.381	10	- .516	1.12	- .557
41 DB	115	1.690	17	.259	.87	-1.310
42 KF	75	- .323	5	-1.069	1.33	.075
43 KM	74	- .374	7	- .847	1.35	.136
44 RF	103	1.086	32	1.918	.97	-1.006
45 BP	68	- .676	5	-1.069	1.47	.497

SUBJECT	NO. OF FIXATIONS		NO. OF REGRESSIONS		SPAN	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
46 RN	68	- .676	13	- .184	1.47	.497
47 DS	75	- .323	4	-1.179	1.33	.075
48 BP	---	----	---	----	-----	---
49 JP	82	.029	27	1.365	1.22	- .256
50 RB	60	-1.078	10	- .516	1.67	1.099
51 MC	83	.079	8	- .737	1.20	- .316
52 RR	89	.381	6	- .958	1.12	- .557
53 SM	56	-1.280	10	- .516	1.79	1.461
54 TS	67	- .726	14	- .073	1.49	.557
55 PL	54	-1.380	7	- .847	1.85	1.642
56 LK	80	- .072	12	- .294	1.25	- .166
57 KE	---	----	---	----	-----	----
58 OC	61	-1.028	16	.148	1.64	1.009
59 IK	100	.935	22	.812	1.00	- .919
60 SI	62	- .978	9	- .626	1.61	.919
61 DT	56	-1.280	4	-1.179	1.79	1.461
MEAN	81.42		14.66		1.305	
SD	19.87		9.04		.332	

	SPAN-REGRESSIONS		DURATION (SEC/F)		WORDS/MINUTE	
SUBJECT	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
1 BH	2.22	1.906	.264	−1.289	484	3.370
2 FR	1.85	.821	.278	− .921	313	.875
3 AA	1.61	.117	.287	− .684	255	.029
4 SC	1.56	− .029	.257	−1.474	288	.511
5 SY	1.33	− .704	.284	− .763	227	− .379
6 DH	1.92	1.026	.313	0.000	368	1.678
7 MB	1.67	.293	.307	− .158	260	.102
8 MR	1.54	− .088	.279	− .895	251	− .029
9 GM	----	----	----	----	----	----
10 TG	1.89	.938	.328	.395	241	− .175
11 GS	1.35	− .645	.297	− .421	249	− .058
12 TD	2.33	2.229	.372	1.553	351	1.430
13 HW	1.52	− .147	.302	− .289	229	− .350
14 MB	1.56	− .029	.312	− .063	260	.102
15 MC	1.11	−1.349	.331	.474	155	−1.430
16 KH	1.12	−1.320	.316	.079	146	−1.561
17 DC	2.17	1.760	.357	1.158	336	1.211
18 BP	1.15	−1.232	.390	2.026	160	−1.357
19 CS	2.08	1.496	.369	1.474	296	.627
20 DJ	1.20	−1.085	.311	− .053	219	− .496
21 PT	1.52	− .147	.366	1.395	171	− .107
22 RN	1.01	−1.642	.333	.526	134	−1.737
23 DS	1.30	− .792	.359	1.211	172	−1.182
24 DF	1.56	− .029	.313	0.000	270	.248
25 JI	1.43	− .411	.266	−1.237	217	− .525
26 GK	1.56	− .029	.282	− .816	276	.335
27 DK	1.49	− .235	.402	2.342	171	−1.197
28 LL	1.22	−1.026	.345	.842	167	−1.255
29 FM	1.52	− .147	.402	2.342	199	− .788
30 JH	1.32	− .733	.331	.474	189	− .934
31 LM	1.85	.821	.317	.105	296	.627
32 VW	1.30	− .792	.325	.316	194	− .861
33 DW	1.19	−1.114	.281	− .842	202	− .744
34 TB	1.54	− .088	.300	− .342	256	.044
35 EM	1.69	.352	.360	1.237	228	− .365
36 DM	1.37	− .587	.327	.368	224	− .423
37 MJ	2.00	1.261	.290	− .605	333	1.167
38 MB	1.35	− .645	.292	− .553	242	− .161
39 DT	1.37	− .587	.266	−1.237	233	− .292
40 JS	1.27	− .880	.357	1.158	189	− .923
41 DB	1.02	−1.613	.320	.184	163	−1.313
42 KF	1.43	− .411	.285	− .737	281	.408
43 KM	1.49	− .235	.276	− .974	294	.598
44 RF	1.41	− .469	.282	− .816	207	− .671
45 BP	1.59	.059	.286	.711	307	.788
46 RN	1.82	.733	.362	1.289	244	− .131
47 DS	1.51	− .469	.257	−1.474	311	.846
48 BP	----	----	----	----	----	----
49 JP	1.82	.733	.329	.421	224	− .423

SUBJECT	SPAN-REGRESSIONS		DURATION (SEC/F)		WORDS/MINUTE	
	DATA	z-SCORE	DATA	z-SCORE	DATA	z-SCORE
50 RB	2.00	1.261	.292	− .553	343	1.313
51 MC	1.33	− .704	.331	.474	219	− .496
52 RR	1.20	−1.085	.271	−1.105	249	− .058
53 SM	2.17	1.760	.368	1.447	291	.554
54 TS	1.89	.938	.285	− .737	314	.890
55 PL	2.13	1.642	.283	− .789	392	2.028
56 LK	1.47	− .293	.319	.158	235	− .263
57 KE	----	---	----	---	---	---
58 OC	2.22	1.906	.258	−1.447	381	1.868
59 IK	1.28	− .850	.275	−1.000	218	− .511
60 SI	1.89	.117	.339	.684	286	.481
61 DT	1.92	.645	.339	.684	316	.919
MEAN	1.570		.313		253.0	
SD	.341		.038		68.5	

APPENDIX C

DISTANCE ROCK MEASUREMENTS

TOTAL ERRORS

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
1 BH	1	− .925	8	.965
2 JR	0	− .925	4	− .272
3 AA	0	− .925	2	− .890
4 SC	3	.717	2	− .890
5 GY	0	− .925	1	−1.199
6 DH	1	− .377	3	− .581
7 MB	5	1.811	3	− .581
8 MR	3	.717	6	.347
9 GM	−	———	−	———
10 TG	0	− .925	4	− .272
11 GS	1	− .377	2	− .890
12 TD	3	.717	2	− .890
13 HW	0	− .925	5	.037
14 MB	1	− .377	4	− .272
15 MC	0	− .925	5	.037
16 KH	4	1.264	4	− .272
17 DC	2	.170	1	−1.199
18 BP	4	1.264	6	.347
19 CS	0	− .925	5	.037
20 DJ	0	− .925	9	1.274
21 PT	8	3.452	12	2.202
22 RN	4	1.264	1	−1.199
23 KS	0	− .925	4	− .272
24 DF	1	− .377	3	− .581
25 JI	6	2.358	3	− .581
26 GK	3	.717	6	.347
27 DK	1	− .377	3	− .581
28 LL	0	− .925	8	.965
29 JM	0	− .925	12	2.202
30 JH	0	− .925	1	−1.199
31 LM	3	.717	9	1.274
32 WV	1	− .377	7	.656
33 KW	2	.170	6	.347
34 TB	2	.170	7	.656
35 EM	1	− .377	10	1.583
36 DM	0	− .925	4	− .272
37 MJ	4	1.264	17	3.748
38 MB	2	.170	3	− .581
39 DT	3	.717	2	− .890
40 JS	3	.717	4	− .272
41 DB	3	.717	10	1.583
42 KF	0	− .925	1	−1.199

TOTAL ERRORS

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
43 KM	0	− .925	4	− .272
44 RF	0	− .925	4	− .272
45 BP	0	− .925	3	− .581
46 RN	0	− .925	3	− .581
47 DS	3	.717	4	− .272
48 BP	−	----	−	----
49 JP	1	− .377	2	− .890
50 RB	3	.717	4	− .272
51 MC	3	.717	3	− .581
52 RR	0	− .925	1	−1.199
53 MC	0	− .925	6	.347
54 TS	1	− .377	7	.656
55 PL	3	.717	7	.656
56 LK	3	.717	9	1.274
57 KE	−	----	−	----
58 DC	4	−1.264	1	−1.199
59 IK	0	− .925	7	.656
60 SI	0	− .925	4	− .272
61 DT	3	.717	5	.037
MEAN	1.690		4.879	
SD	1.828		3.234	

CYCLES/MINUTE

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
1 BH	30.0	- .546	28.1	1.005
2 JR	26.8	-1.212	18.3	-1.625
3 AA	36.1	.723	21.6	- .739
4 SC	29.5	- .650	22.6	- .471
5 GY	34.7	.432	20.4	-1.061
6 DH	28.1	- .942	26.8	.656
7 MB	31.1	- .318	28.1	1.005
8 MR	33.4	.078	24.6	.066
9 GM	----	----	----	----
10 TG	30.0	- .546	22.7	- .444
11 GS	41.2	1.784	27.3	.790
12 TD	28.1	- .942	24.6	.066
13 HW	35.4	.577	23.3	- .283
14 MB	31.6	- .213	20.4	-1.061
15 MC	33.4	.161	22.6	- .471
16 KH	33.4	.161	21.3	- .820
17 DC	31.1	- .318	28.1	1.005
18 BP	27.7	-1.025	22.1	- .605
19 CS	26.8	-1.212	26.8	.656
20 DJ	32.8	.036	24.1	- .068
21 PT	29.0	- .754	27.3	.790
22 RN	26.8	-1.212	24.6	.066
23 KS	29.5	- .650	19.5	-1.303
24 DF	42.2	1.992	33.4	2.427
25 JI	36.9	.889	27.3	.790
26 GK	34.0	.286	23.8	- .122
27 DK	32.8	.036	20.1	-1.142
28 LL	32.8	.036	21.3	- .820
29 JM	32.8	.036	20.6	-1.008
30 JH	27.7	-1.025	23.3	- .283
31 LM	30.0	- .546	23.9	- .122
32 WV	25.0	-1.587	16.9	-2.000
33 KW	32.8	.036	26.8	.656
34 TB	42.2	1.992	32.8	2.266
35 EM	26.4	-1.295	18.3	-1.625
36 DM	28.6	- .838	22.2	- .578
37 MJ	31.6	- .213	20.6	-1.008
38 MB	28.6	- .838	26.8	.656
39 DT	34.7	.432	23.9	- .122
40 JS	28.1	- .942	23.6	- .203
41 DB	31.1	- .318	29.0	1.246
42 KF	28.1	- .942	25.7	.361
43 KM	41.2	1.784	31.1	1.810
44 RF	35.4	.577	23.3	- .283
45 BP	40.2	1.576	31.1	1.810
46 RN	38.5	1.222	25.3	.254
47 DS	41.2	1.784	26.8	.656

CYCLES/MINUTE

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
48 BP	----	----	----	----
49 JP	35.4	.577	25.7	.361
50 RB	26.1	−1.358	18.3	−1.625
51 MC	35.4	.577	29.0	1.246
52 RR	27.7	−1.025	24.6	.066
53 MC	32.2	− .089	23.3	− .283
54 TS	40.2	1.576	20.8	− .954
55 PL	30.0	− .546	20.4	−1.061
56 LK	36.9	.889	27.3	.790
57 KE	----	----	----	.----
58 DC	34.0	.286	26.8	.656
59 IK	43.2	2.221	29.0	1.246
60 SI	25.7	−1.441	19.9	−1.195
61 DT	36.1	.723	24.3	− .015
MEAN	32.63		24.35	
SD	4.81		3.73	

ALTERNATIONS/MINUTE

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
1 BH	59.9	− .551	56.2	1.326
2 JR	53.6	−1.206	36.5	−1.992
3 AA	72.2	.728	43.2	− .864
4 SC	59.0	− .644	45.2	− .527
5 GY	69.4	.437	40.7	−1.285
6 DH	56.1	− .946	53.6	.888
7 MB	62.1	− .322	56.2	1.326
8 MR	66.7	.156	49.2	.147
9 GM	-----	----	-----	----
10 TG	59.9	− .551	45.4	.493
11 GS	82.3	1.778	54.5	1.039
12 TD	56.1	− .946	49.2	.147
13 HW	70.8	.582	46.5	− .308
14 MB	63.2	− .208	40.7	−1.285
15 MC	66.8	.167	45.2	− .527
16 KH	66.8	.167	42.6	− .965
17 DC	62.1	− .322	56.2	1.326
18 BP	55.3	−1.029	44.2	− .685
19 CS	53.6	−1.206	53.6	.888
20 DJ	65.5	.031	28.1	−3.407
21 PT	58.0	− .748	54.5	1.039
22 RN	53.6	−1.206	49.2	.147
23 KS	59.0	− .644	38.9	−1.588
24 DF	84.3	1.986	66.8	3.111
25 JI	73.8	.894	54.5	−2.329
26 GK	68.0	.291	47.8	− .089
27 DK	65.5	.031	40.2	−1.369
28 LL	65.5	.031	42.6	− .965
29 JM	65.5	.031	41.2	−1.201
30 JH	55.3	−1.029	46.5	− .308
31 LM	59.9	− .551	47.8	− .089
32 WV	49.9	−1.591	33.7	−2.464
33 KW	65.6	.042	53.6	.888
34 TB	84.3	1.986	65.6	2.909
35 EM	52.8	−1.289	36.5	−1.992
36 DM	57.1	− .842	44.3	− .679
37 MJ	63.2	− .208	41.2	−1.201
38 MB	57.1	− .842	53.6	.888
39 DT	69.4	.437	47.8	− .258
40 JS	56.1	− .946	47.2	− .190
41 DB	62.1	− .322	58.0	1.630
42 KF	56.1	− .946	51.3	.500
43 KM	82.3	1.778	62.1	2.320
44 RF	70.8	.582	46.6	− .291
45 BP	80.4	1.581	62.1	2.320
46 RN	76.9	1.217	50.6	.383
47 DS	82.3	1.778	53.6	.888

ALTERNATIONS/MINUTES

SUBJECTS	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
48 BP	----	---	----	---
49 JP	70.8	.582	51.3	.500
50 RB	52.1	-1.362	36.5	-1.992
51 MC	70.8	.582	58.0	1.629
52 RR	55.3	-1.029	49.2	.147
53 MC	64.4	- .083	46.6	- .291
54 TS	80.4	1.581	46.6	-1.133
55 PL	59.9	- .551	40.7	-1.285
56 LK	73.8	.894	54.5	1.039
57 KE	----	---	----	---
58 DC	68.0	.219	53.6	.888
59 IK	86.3	2.194	58.0	1.629
60 SI	51.3	-1.445	39.8	-1.437
61 DT	72.2	.728	48.5	.029
MEAN	65.20		48.33	
SD	9.62		7.94	

44

ERROR ADJUSTED SCORE (CYCLES/MINUTE)

SUBJECT	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
1 BH	29.6	− .479	20.9	− .305
2 JR	26.8	−1.030	17.0	−1.286
3 AA	36.0	.785	20.8	−..330
4 SC	28.0	− .796	22.3	.047
5 GY	28.1	− .776	20.0	− .531
6 DH	34.1	− .410	25.5	.852
7 MB	28.4	− .717	26.7	1.154
8 MR	31.8	− .045	22.1	− .003
9 GM	-----	----	----	----
10 TG	30.1	− .381	21.2	− .229
11 GS	40.2	1.620	26.4	1.079
12 TD	32.9	.173	23.8	.424
13 HW	35.5	.687	21.3	− .204
14 MB	31.2	− .163	18.6	− .884
15 MC	33.5	.291	21.1	− .255
16 KH	23.5	−1.680	19.9	− .556
17 DC	30.0	− .400	27.6	1.381
18 BP	29.9	− .420	19.9	− .556
19 CS	43.4	2.248	24.5	.601
20 DJ	32.8	.153	11.9	−2.569
21 PT	25.0	−1.389	21.8	− .078
22 RN	25.0	−1.389	24.2	.525
23 KS	29.5	− .499	18.1	−1.009
24 DF	41.4	1.853	25.9	.953
25 JI	33.1	.212	25.9	.953
26 GK	32.2	.034	18.0	−1.034
27 DK	32.2	.034	19.0	− .783
28 LL	32.8	.153	18.5	− .909
29 JM	32.8	.153	16.4	−1.437
30 JH	27.7	− .855	22.8	.173
31 LM	28.6	− .677	20.7	− .355
32 WV	24.6	−1.468	14.8	−1.840
33 DW	31.7	− .064	24.1	.500
34 TB	40.7	1.714	28.9	1.708
35 EM	25.9	−1.211	15.1	−1.764
36 DM	28.6	− .677	20.3	− .456
37 MJ	29.6	− .479	14.7	−1.865
38 MB	27.7	− .855	25.5	.852
39 DT	32.9	.173	23.2	.274
40 JS	26.7	−1.053	22.0	− .028
41 DB	29.5	− .499	24.0	.474
42 DK	28.1	− .776	25.2	.777
43 DM	41.2	1.813	28.9	1.708
44 RF	35.4	.668	27.5	1.355
45 BP	40.2	1.615	29.5	1.859
46 RN	38.5	1.279	23.9	.450
47 DS	38.9	1.358	25.0	.726

ERROR ADJUSTED SCORE (CYCLES/MINUTE)

SUBJECT	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
48 BP	----	----	----	---
49 JP	34.9	.568	24.8	.676
50 RB	24.8	-1.428	17.0	-1.286
51 MC	33.7	.331	27.5	1.355
52 RR	27.7	- .835	24.2	.525
53 MC	32.2	.034	21.0	- .280
54 TS	39.7	1.520	18.4	- .934
55 PL	28.6	- .677	17.9	-1.060
56 LK	35.0	.588	23.6	.374
57 KE	----	----	----	---
58 DC	31.6	.084	26.4	1.079
59 IK	43.2	2.208	25.7	.903
60 SI	25.7	-1.250	18.6	- .884
61 DT	34.1	.410	22.1	.003
MEAN	32.026		22.112	
SD	5.060		3.975	

ERRORS/MINUTE

SUBJECT	20/80 LETTERS DATA	z-SCORE	20/25 LETTERS DATA	z-SCORE
1 BH	1.02	− .472	6.56	1.041
2 JR	0.00	− .979	2.47	− .563
3 AA	0.00	− .979	1.46	− .958
4 SC	3.00	.512	1.56	− .919
5 GY	0.00	− .979	.69	−1.260
6 DH	1.18	− .392	2.73	− .461
7 MB	5.26	1.636	2.86	− .409
8 MR	3.41	.716	5.00	.429
9 GM	----	----	----	----
10 TG	0.00	− .979	3.08	− .323
11 GS	1.39	− .288	1.85	− .806
12 TD	3.70	.860	1.67	− .876
13 HW	0.00	− .979	3.94	.014
14 MB	1.08	− .442	2.76	− .449
15 MC	0.00	− .979	3.91	.002
16 KH	3.42	.721	2.90	− .394
17 DC	2.11	.070	.95	−1.158
18 BP	4.35	1.183	4.51	.237
19 CS	0.00	− .979	4.55	.253
20 DJ	0.00	− .979	4.29	.151
21 PT	7.84	2.918	11.11	2.824
22 RN	3.64	.831	.83	−1.205
23 KS	0.00	− .979	2.63	− .500
24 DF	1.43	− .268	3.41	− .194
25 JI	7.50	2.749	2.78	− .441
26 GK	3.45	.736	4.88	.382
27 DK	1.11	− .427	2.04	− .731
28 LL	0.00	− .979	5.80	.743
29 JM	0.00	− .979	8.40	1.762
30 JH	0.00	− .979	.79	−1.221
31 LM	3.05	.537	7.32	1.339
32 WV	.85	− .556	4.00	.037
33 DW	2.22	.125	5.45	.606
34 TB	2.86	.443	7.28	1.519
35 EM	.89	− .536	6.17	.888
36 DM	0.00	− .979	3.01	− .351
37 MJ	4.30	1.159	11.89	3.130
38 MB	1.94	− .014	2.73	− .461
39 DT	3.53	.776	1.63	− .892
40 JS	2.86	.443	3.20	− .276
41 DB	3.16	− .592	9.80	2.311
42 KF	0.00	− .979	.87	−1.190
43 KM	0.00	− .979	4.21	.120
44 RF	0.00	− .979	3.15	− .296
45 BP	0.00	− .979	3.16	− .292
46 RN	0.00	− .979	2.56	− .527
47 DS	4.17	1.094	3.64	− .104

ERRORS/MINUTE

SUBJECT	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
48 BP	------	----	------	----
49 JP	1.20	- .382	1.74	- .849
50 RB	2.65	.338	2.47	- .563
51 MC	3.61	.816	2.94	- .378
52 RR	0.00	- .979	.83	-1.205
53 MC	5.61	1.810	4.76	.335
54 TS	1.37	- .298	4.96	.414
55 PL	3.06	.542	4.83	.363
56 LK	3.75	.886	8.33	1.735
57 KE	------	----	------	----
58 DC	4.60	1.308	.91	-1.174
59 IK	0.00	- .979	6.93	1.186
60 SI	0.00	- .979	2.70	-..472
61 DT	3.66	.840	4.10	.076
MEAN	1.969		3.905	
SD	2.012		2.551	

ERRORS/LETTER READ

	20/80 LETTERS		20/25 LETTERS	
SUBJECT	DATA	z-SCORE	DATA	z-SCORE
1 BH	.017	− .380	.133	.957
2 JR	.000	− .942	.067	− .269
3 AA	.000	− .942	.033	− .900
4 SC	.050	.709	.033	− .900
5 GY	.000	− .942	.017	−1.197
6 DH	.017	− .380	.050	− .584
7 MB	.084	1.830	.050	− .584
8 MR	.050	.709	.010	.344
9 GM	-----	----	-----	---
10 TG	.000	− .942	.067	− .269
11 GS	.017	− .380	.033	− .900
12 TD	.050	.709	.033	− .900
13 HW	.000	− .942	.084	.047
14 MB	.017	− .380	.067	− .269
15 MC	.000	− .942	.084	.047
16 KH	.067	1.271	.067	− .269
17 DC	.033	.148	.017	−1.197
18 BP	.067	1.271	.010	.344
19 CS	.000	− .942	.084	.047
20 DJ	.000	− .942	.150	1.272
21 PT	.133	3.450	.200	2.200
22 RN	.067	1.271	.017	−1.197
23 KS	.000	− .942	.067	− .269
24 DF	.017	− .380	.050	− .584
25 JI	.100	2.360	.050	− .584
26 GK	.050	.709	.100	.344
27 DK	.017	− .380	.050	− .584
28 LL	.000	− .942	.133	.957
29 JM	.000	− .942	.200	2.200
30 JH	.000	− .942	.017	−1.197
31 LM	.050	.709	.150	1.272
32 WV	.017	− .380	.117	.660
33 DW	.033	.148	.100	.344
34 TB	.033	.148	.117	.660
35 EM	.017	− .380	.167	1.588
36 DM	.000	− .942	.067	− .269
37 MJ	.067	1.271	.283	3.741
38 MB	.033	.148	.050	− .584
39 DT	.050	.709	.033	− .900
40 JS	.050	.709	.067	− .269
41 DB	.050	.709	.117	1.588
42 KF	.000	− .942	.017	−1.197
43 KM	.000	− .942	.067	− .269
44 RF	.000	− .942	.067	− .269
45 BP	.000	− .942	.050	− .584
46 RN	.000	− .942	.050	− .584
47 DS	.050	.709	.067	− .269

ERRORS/LETTER READ

| SUBJECT | 20/80 LETTERS | | 20/25 LETTERS | |
	DATA	z-SCORE	DATA	z-SCORE
48 BP	-----	----	-----	----
49 JP	.017	− .380	.033	− .900
50 RB	.050	.709	.067	− .269
51 MC	.050	.709	.050	− .584
52 RR	.000	− .942	.017	−1.197
53 MC	.000	− .942	.100	.344
54 TS	.017	− .380	.117	.660
55 PL	.050	.709	.117	.660
56 LK	.050	.709	.150	1.272
57 KE	-----	----	-----	----
58 DC	.067	1.271	.017	−1.197
59 IK	.000	− .942	.117	.660
60 SI	.000	− .942	.067	− .269
61 DT	.050	.709	.084	.047
MEAN	.0385		.0815	
SD	.0303		.0539	

AVERAGE RESPONSE TIME/LETTER

	20/80 LETTERS		20/25 LETTERS	
SUBJECT	DATA	z-SCORE	DATA	z-SCORE
1 BH	.98	.550	1.22	− .167
2 JR	1.10	1.466	1.62	1.635
3 AA	.82	− .672	1.37	.509
4 SC	1.00	.702	1.28	.103
5 GY	1.05	1.084	1.45	.869
6 DH	.85	− .443	1.10	− .707
7 MB	.95	.321	1.05	− .932
8 MR	.88	− .824	1.20	− .257
9 GM	-----	----	-----	----
10 TG	.98	.550	1.30	.194
11 GS	.72	−1.435	1.08	− .797
12 TD	.85	− .443	1.20	− .257
13 HW	.83	− .595	1.27	.058
14 MB	.93	.168	1.45	.869
15 MC	.88	− .214	1.28	.104
16 KH	1.17	2.000	1.38	.554
17 DC	.95	.321	1.05	− .932
18 BP	.92	.092	1.33	.329
19 CS	.68	−1.740	1.10	− .707
20 DJ	.90	− .061	2.10	3.797
21 PT	1.02	.855	1.08	− .797
22 RN	1.10	1.466	1.20	− .257
23 KS	1.00	.702	1.52	1.185
24 DF	.70	−1.588	.88	−1.698
25 JI	.80	− .824	1.08	− .797
26 GK	.87	− .290	1.23	− .122
27 DK	.90	− .061	1.47	.959
28 LL	.90	− .061	1.38	.554
29 JM	.90	− .061	1.43	.779
30 JH	.92	.092	1.27	.059
31 LM	.98	.550	1.23	− .122
32 WV	1.18	2.076	1.75	2.221
33 DW	.90	− .061	1.10	− .707
34 TB	.70	−1.588	.90	−5.662
35 EM	1.12	1.618	1.62	1.635
36 DM	1.03	.931	1.33	.329
37 MJ	.93	.168	1.43	.779
38 MB	1.03	.931	1.10	− .707
39 DT	.85	− .443	1.23	− .121
40 JS	1.05	1.084	1.25	− .032
41 DB	.95	.321	1.02	−1.068
42 KF	.85	− .443	1.15	− .482
43 KM	.72	−1.435	.95	−1.383
44 RF	.83	− .595	1.27	.059
45 BP	.73	−1.359	.95	−1.383
46 RN	.77	−1.053	1.17	− .392
47 DS	.72	−1.435	1.10	− .707

AVERAGE RESPONSE TIME/LETTER

SUBJECT	20/80 LETTERS		20/25 LETTERS	
	DATA	z-SCORE	DATA	z-SCORE
48 BP	-----	-----	-----	----
49 JP	.83	- .595	1.15	- .482
50 RB	1.13	1.695	1.62	1.635
51 MC	.83	- .595	1.02	-1.068
52 RR	.92	.092	1.20	- .257
53 MC	1.07	1.236	1.26	.014
54 TS	.73	-1.359	1.41	.689
55 PL	.98	.549	1.45	.869
56 LK	.88	- .824	1.08	- .797
57 KE	-----	----	-----	----
58 DC	.87	- .290	1.10	- .707
59 IK	.68	-1.740	1.01	-1.113
60 SI	1.13	1.695	1.43	1.005
61 DT	.82	- .672	1.22	- .167
MEAN	.908		1.257	
SD	.131		.222	