Visual efficiency as related to reading achievement at the fourth grade level

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Abstract
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Visual Efficiency as Related to
Reading Achievement at the Fourth Grade Level

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Pacific University College of Optometry
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We would like to extend our appreciation for the help and cooperation of the following individuals:

Principals and participating faculty of Kahaluu Elementary, Kaneohe Elementary and Maunawili Elementary Schools;

Dr. Harold I. Ayabe (statistical consultant);

and fellow Optometry students who assisted in screening the children.
INTRODUCTION

Reading is an integral part of a child's educational process. Because all aspects of vision are involved with reading, inefficiencies within the system may profoundly reduce a child's potential academic achievement. Research done by Coleman showed a high correlation between visual perception and reading accuracy. This strongly supports the view that vision as a total process is involved in reading. Early detection of these deficiencies may enable concerned individuals to correct them before they can lead to more serious consequences affecting the child's reading level.

Shorr and Svagr's research concluded that although an individual might be deficient in certain perceptual skill areas he will often still be able to compensate for them using other skills. The area involving binocular coordination and efficiency however was the one perceptual motor skill group that could not be compensated. Shorr and Svagr also emphasized that relationships between reading and embedded ocular defects (i.e. astigmatism, myopia and strabismus) tend to be minimal. However, they found that these defects may inhibit learning if compounded with other visual problems such as convergence (centering) and accommodation (focusing). Accommodation and convergence imbalances cause a dilemma for the child as he is forced to choose between seeing single and seeing clearly. This problem is further aggravated by the fact that the child must utilize his
accommodative-convergence system while looking between his desk and the chalkboard.

Reading for long periods of time requires sustained accommodation and a series of word-to-word fixations. Fixations are the heart of the visual reading act. They occupy fully 90% of the time spent in reading, while interfixations and return sweeps (saccadic movements) account for the remaining 10%. Spache states that the majority of all reading comprehension occurs during the fraction of a second (about one-third for a young child and one-fourth for a college student) that each fixation occupies. He reports that as reading material becomes more difficult the duration of each fixation increases.

A young elementary school-aged child will fixate approximately 200 times while reading 100 words, which means that he must point and focus his eyes accurately 200 times. Because of this, it is important that a child's fixations be accurate and accommodative-convergence system efficient. Without this efficiency, word recognition is reduced and comprehension is decreased. Gilbert has found that even when it may appear that a person is functioning normally on ordinary measures of comprehension and rate, he will in actuality be employing inefficient and harmful visual patterns.

Starnes has found that a child's visual ability affects how well he will do on a reading achievement test. He found that the children who were good readers had a tendency to perform well on pursuit movement tasks. Conversely, the children who were poor readers had a tendency towards inaccurate and jerky pursuit (tracking) movements.
Refractive error appears to have little statistical significance when it comes to reading achievement in children who receive passing grades in reading. However, according to Eames, it does become significant when children who are failing in reading are taken into consideration. In his study, he found almost twice as many hyperopes in the group with lowered reading achievement than in the passing group. Starnes found no real interaction at all between visual acuity and reading ability in children, although he did note a higher incidence of myopia in good readers and hyperopia in poor readers.

The purpose of our study was to research the relationship between visual efficiency and reading achievement. Visual efficiency was determined by evaluating several visual parameters: visual acuities, accommodative facility, fusional ability and ocular motilities. Reading achievement was determined by looking at each child's Stanford Achievement Test reading scores.

Visual demands differ with different stages of reading. In the early stages visual perception, visual memory, laterality, visual memory control and eye-hand coordination play an important role. These baseline levels of proficiency necessary to begin reading are those of an average six year old. In later stages they play a decreasing role in visual efficiency once basic word recognition skills are mastered.

Fourth graders were selected for our study because research indicates that the reading task becomes more difficult for this age group. Cutts reported that in the third or fourth grade sentences, paragraphs and content become more complex. In other
words, the emphasis shifts from "learning to read" to "reading to learn". The child no longer is being taught the mechanics of reading but is now required to garner information from what he is reading.

Flax maintains that a reasonable degree of competence in reading must be achieved before a child can move from primarily word recognition to using reading skill to acquire information. According to Flax, when a higher level of efficiency in reading is required, borderline amounts of fusional and/or accommodative-convergence instability will begin to interfere with reading success. Therefore, a child entering school with a binocular vision problem may not be handicapped by it to a significant degree until the third grade or later.
PROCEDURE

Subjects consisted of 113 fourth grade students from the Windward Oahu school district, Hawaii. Of these, 17 could not be included in our results due to uncorrected refractive error and/or unavailability of Stanford Achievement Test reading scores.

Seven stations were set up for each screening and manned by Pacific University Optometry students. Each station was designed to evaluate a different parameter of visual efficiency. The stations were as follows:

Station #1 - Distance Snellen visual acuity
Station #2 - Near Snellen visual acuity
Station #3 - Accommodative Rock
Station #4 - Prism Rock
Station #5 - Stern Saccadic Fixation Test
Station #6 - Pierce Saccade Test
Station #7 - Groffman Visual Tracing Test

With the exception of the distance and near acuity stations, students were moved through the stations randomly.

Snellen visual acuities were used to measure the ability of each child to see an object clearly both at distance and at near and were taken to rule out students with less than 20/30 acuity.

The Accommodative Rock was done to assess the focusing flexibility of the eyes by using +2.00 D/-2.00 D lenses flipped alternately. The children were asked to flip the lenses and call
aloud individual letters from a printed page (letter chart) as soon as they could see the letters clearly. (Appendix 1)

The Prism Rock was done to evaluate the pointing mechanism of the eyes by employing 8° Base In/8° Base Out lenses flipped alternately. The children were asked to flip the lenses and call aloud individual letters from a printed page (Appendix 1) as soon as they could see only one clear image of each letter.

The Accommodative Rock and Prism Rock scores were determined by timing each child for 60 seconds and noting the number of flips made at 30-second intervals.

The Stern Saccadic Fixation Test was administered to assess those eye movements that are most like those used in reading. It requires a timed reading of letters off a printed page at a normal reading distance. (Appendix 2) Each child was told to call the letters aloud as quickly and as accurately as he/she could.

The Pierce Saccade Test assesses saccadic eye movements as well as pursuit-type eye movements. Numbers are called out alternately from two vertical columns on either side of the page in each of three subtests. Test I included horizontal lines indicating where the eyes were to move (Appendix 3), test II eliminated those lines (Appendix 4) and test III had smaller vertical spaces between the numbers (Appendix 5). The children were asked to call out the numbers as quickly and as accurately as they could.

The Stern Saccadic Fixation and Pierce Saccade test scores incorporated the total time needed to complete the task(s) with a two-second penalty for every error made.
The Groffman Visual Tracing Test was used to evaluate the pursuit-type eye movements. Evenly spaced letters are located at the top of the page with corresponding numbers on the bottom of the page. Each letter is connected to a number by a line which curves and intertwines. (Appendix 6) The children were told to visually trace as quickly and accurately as they could from letter to number.

For the Groffman Visual Tracing Test the amount of time needed to reach a number was converted to a point score via a normed scale. The points were then combined for a total score.
RESULTS

Using regression analysis and the Pearson r, (see Table 1) it was discovered that of the three eye movement measures, Stern Saccadic Fixation Test (Stern), Pierce Saccade Test (Pierce) and Groffman Visual Tracing Test (Groffman), only the Groffman and Pierce scores were significantly related to standardized reading scores: the Stanford Achievement Test Reading Comprehension scores (SATRC), Word Study scores (SATWS) and Total Reading scores (SATTR). The Stern was not reliably related to any of the reading scores.

As hypothesized the Groffman correlated positively with each of the standardized reading scores: SATRC \((r = 0.246, \ df = 96, \ p < 0.05)\), SATWS \((r = 0.292, \ df = 96, \ p < 0.01)\) and SATTR \((r = 0.375, \ df = 96, \ p < 0.01)\). The positive relationship indicates that those who show good tracking ability also tend to do well on reading tests.

The Pierce correlated negatively with two of the standardized reading scores: SATRC \((r = -0.275, \ df = 96, \ p < 0.01)\) and SATTR \((r = -0.227, \ df = 96, \ p < 0.05)\). The negative relationship indicates that those who show good saccadic ability and therefore low scores on the Pierce, will tend to do well on reading comprehension tests. This negative relationship with the SATRC and SATTR was expected. However, the statistically non-significant relationship with the SATWS \((r = -0.142, \ df = 96, \ n.s.)\) was not expected.
The hypothesis that the Stern was related to reading scores was not supported: SATRC \((r = -0.199, \text{ df} = 96, \text{ n.s.})\), SATWS \((r = -0.041, \text{ df} = 96, \text{ n.s.})\) and SATTR \((r = -0.122, \text{ df} = 96, \text{ n.s.})\).

According to the regression analysis the Groffman and Pierce contributed most in predicting the SAT reading scores. The percentage accounted for by all parameters tested was 19.1\% on the SATRC, 14.4\% on the SATWS and 20.8\% on the SATTR.

To predict the SATRC, SATWS or SATTR score of an individual the following predictive equations may be used:

\[
\begin{align*}
\text{SATRC} &= 53.3 + X (-3.11) + X (-0.07) + X (-0.16) + X (0.31) \\
&\quad + X (-0.04) + X (-0.19) + X (-1.07) + X (0.51) + \\
&\quad X (0.79) \\
\text{SATWS} &= 48.5 + X (0.03) + X (0.01) + X (-0.12) + X (0.43) + \\
&\quad X (-0.16) + X (0.21) + X (-1.57) + X (0.73) + \\
&\quad X (0.18). \\
\text{SATTR} &= 43.8 + X (0.21) + X (-0.02) + X (-0.12) + X (0.45) + \\
&\quad X (0.10) + X (-0.14) + X (-0.86) + X (0.34) + \\
&\quad X (0.44). \\
\end{align*}
\]

Where: \(X = \text{male or female (male} = 0, \text{ female} = 1)\),

1. \(X = \text{Stern score,}\)
2. \(X = \text{Pierce score,}\)
3. \(X = \text{Groffman score,}\)
4. \(X = \text{Accommodative Rock score (first 30 seconds),}\)
5. \(X = \text{Accommodative Rock score (second 30 seconds),}\)
6. \(X = \text{Prism Rock score (first 30 seconds),}\)
7. \(X = \text{Prism Rock score (second 30 seconds),}\)
8. \(X = \text{Snellen acuity score (both eyes at 40 cm.)}\)

It should be noted that each predictor score should be
divided by 10 as the decimal points in the reading scores were not accounted for.

Accommodative Rock scores and Prism Rock scores showed no significant correlation or predictive value with the SATRC, SATWS or SATTR scores. (See Tables 1 thru 4.)
Table 1: Intercorrelations Between Gender, Stanford Achievement Test Reading scores and Visual Parameters.

<table>
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<tr>
<th></th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
<th>X10</th>
<th>X11</th>
<th>X12</th>
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<td>0.007</td>
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<td>-0.153</td>
<td>0.120</td>
<td>0.129</td>
<td>0.215</td>
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<td>0.129</td>
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<td>-0.275</td>
<td>0.246</td>
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<td>-0.07</td>
<td>0.064</td>
<td>0.027</td>
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<td>-0.024</td>
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<td>0.082</td>
<td>0.860</td>
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<td>0.576</td>
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<td>-0.018</td>
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<td>-0.235</td>
<td>0.146</td>
<td>0.618</td>
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* p < 0.05
** p < 0.01
Table 2: Regression Analysis Source Table for Predicting Stanford Achievement Test Reading Comprehension Scores.

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Table 3: Regression Analysis Source Table for Predicting Stanford Achievement Test Word Study Scores.

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Table 4: Regression Analysis Source Table for Predicting Stanford Achievement Test Total Reading Scores.

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<th>F-VALUE</th>
<th>PR &gt; F</th>
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DISCUSSION

A positive correlation was found between the Groffman Visual Tracing Test and the Stanford Achievement Test Reading Comprehension, Word Study and Total Reading sections. This emphasizes that good eye tracking ability plays an important role in reading.

The Pierce Saccade Test showed a negative correlation with the Reading Comprehension and Total Reading sections. This indicates that those who show good saccadic ability will also tend to do well on reading comprehension tests.

The Stern Saccadic Fixation Test was developed to most accurately simulate the reading process and previous studies have shown a strong relationship between the Stern and reading scores. Therefore we expected the Stern to show a positive correlation with the Stanford Achievement Test reading scores. However, a significant correlation was not found, which may indicate that efficient fine saccadic eye movements may not be a good predictor of reading achievement at the fourth grade level.

Other parameters studied showed no significant correlation with any of the reading scores. It appears that accommodative facility and fusional ability have no predictive value with respect to reading achievement as long as the student is able to keep the target clear and single.

Although statistical significance was determined for eye movement ability, strong predictive value was not found. Further
investigation may be used to examine the predictive values of other factors with respect to reading scores. Other factors which may be studied are intelligence, accommodative-convergence and visual perception. Differences in variance may then be compared to determine the actual contribution made by eye movement ability.
BIBLIOGRAPHY


Appendix 2

1979

Norman Stern OD, PhD