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Use of the Ober2 system for analysis of eye movements made during reading

Greg S. Koenig
Pacific University

Nathan C. Price
Pacific University

Michael L. Baird
Pacific University

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Abstract

Introduction: The Ober2 system uses infrared reflections to record and analyze eye movements made during reading. The system's ability to analyze data from normal subjects, and the reliability of the data produced by subjects who read standard paragraphs were investigated in this study.

Subjects: Forty-two college students and 20 junior high students participated in the project. All were self-reported normal readers.

Methods: Subjects read 5 different paragraphs during each of two sessions. Ober2 analysis was attempted for each paragraph; analysis of all 10 paragraphs was successful for 38 percent of the college subjects and 20 percent of the junior high subjects. Use of manual calibration procedures did not allow any additional data to be analyzed by the Ober2 system.

Results: Data from 30% of the paragraph presentations could not be analyzed by the Ober2. When analysis was successful, grade equivalent scores based on fixations, span of recognition, regressions, fixation duration, and reading rate were provided. Using mean grade equivalents from the 16 college subjects for whom all 10 paragraphs could be analyzed, significant differences were found between results for two of the test paragraphs. Split-half reliability coefficients for grade equivalent data from the two sessions ranged from 0.84 to 0.95.

Conclusions: Although the Ober2 can provide valuable information on eye movements made during reading, problems exist with respect to its ability to analyze data. The analysis failures that occurred for approximately one-third of the paragraph presentations were frustrating and time consuming. With respect to the standard paragraphs, significant grade equivalent differences were found between several of them. These results suggest that caution be used when interpreting data from the Ober2 reading analysis system.

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USE OF THE OBER2 SYSTEM FOR ANALYSIS OF EYE MOVEMENTS MADE DURING READING

By

GREG S. KOENIG B.S.
NATHAN C. PRICE B.S.
MICHAEL L. BAIRD B.S.

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Advisers:
HANNU LAUKKANEN O.D., M.Ed.
ROBERT L YOLTON PhD, O.D

Greg Koenig by NCP

Greg S. Koenig B.S.

Nathan C. Price

Nathan C. Price B.S.

Michael L. Baird

Michael L. Baird B.S.

Hannu Laukkanen

Hannu Laukkanen O.D., M.Ed.

Robert L Yolton

Robert L. Yolton PhD, O.D.

Biographical Information.

Michael L. Baird graduated with his BS degree in Design Engineering Technology from Brigham Young University in April 1986. Following working as an engineer for 5 years, a career change was made and Pacific University College of Optometry was entered in 1992. While a student at PUCO Michael received a travel fellowship to attend the 1995 American Academy of Optometry Conference in New Orleans, Louisiana. A poster presentation was exhibited discussing the contents of this thesis project. Upon graduation from PUCO Michael plans to practice full scope optometry in a private or partnership practice in the Inter Mountain West.

Greg Koenig completed his undergraduate work at Ricks College in Rexburg, Id. and at the University of Nevada Reno in Reno, NV. He received a BS degree in Visual Science from Pacific University in 1994. Greg received a travel fellowship from the American Academy of Optometry to present a poster about this thesis at the academy Meeting in 1995. After graduation Greg plans to work as an optometrist in Fallon, NV. performing full-scope optometric care.

Nathan C. Price completed his undergraduate work at Ricks College in Rexburg, Id. and Idaho State University in Pocatello, Id.. He received a BS degree in Visual Science from Pacific University in 1994. Nathan received a student travel fellowship from the American Academy of Optometry to attend the Academy meeting in 1995 and present a poster about this thesis project. While at Pacific University Nathan was named an All-American Scholar by the United States Achievement Academy and he was named in Who's-Who Among Students in American Colleges and Universities. After graduating Nathan plans to work in a private optometric practice performing full scope optometric care with an emphasis on visual related learning disabilities and surgical comanagement.

ABSTRACT

Introduction: The Ober2 system uses infrared reflections to record and analyze eye movements made during reading. The system's ability to analyze data from normal subjects, and the reliability of the data produced by subjects who read standard paragraphs were investigated in this study.

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Conclusions: Although the Ober2 can provide valuable information on eye movements made during reading, problems exist with respect to its ability to analyze data. The analysis failures that occurred for

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KEY WORDS

Reading, eye movements, vision, Ober2, reliability, dyslexia, reading disability

INTRODUCTION

As you read this sentence, your brain is performing a complex set of interrelated tasks ranging from photochemical conversion in the retina to executing the eye movements necessary to scan the print. Because your ability to read depends on so many factors, a weak link anywhere in the system can have a significant impact on reading. Some difficulties, such as refractive errors, are relatively easy to detect and remediate. Others, such as the inability to make accurate eye movements during reading, can be more difficult to diagnose and treat.

Eye Movements During Reading

During reading, the eyes do not glide continuously and smoothly along the line of print. Instead they move in a series of 20 to 40 msec long saccades, each of which covers several letters or words depending on the difficulty level of the reading material and the ability of the reader.[1-8]

Between saccades, the eyes hold relatively steady fixation for periods ranging from 100 to 500 msec, with an average of about 200 to 250 msec for adults. Like saccade lengths, fixation durations are influenced by the difficulty of the reading material and skill of the reader.[9]

Normally the eyes move from left to right along the line of print, but even normal readers make occasional right to left regressions to review interesting or poorly understood sections of the text, or to adjust the end points of previous saccades. For normal readers, these right to left regressions account for about 20

percent of the saccades made, but for poor readers the proportion can be much higher.[9]

A normal reader can adjust saccade lengths, fixation times, and the number of regressions to match the difficulty level of material being read. Poor readers can also make these adjustments, but their baseline values are typically quite different from those of normal readers. In general, poor readers have shorter and more frequent saccades, longer fixation durations, more regressions, and slower overall reading rates.[1-9]

Taylor has documented these differences by gathering norms from a large population of readers.[10] Using his norms and standard paragraphs,[11] data from eye movements made during reading can be converted into school grade equivalent scores that allow comparisons to be made between readers.

Eye Movement Assessment

Eye movements can be recorded by using 1) the electrical potentials of the eyes (e.g., electro-oculography), 2) by tracking the Purkinje images produced by reflections from the optical elements of the eyes, 3) by tracking the positions of the pupils, and 4) by using infrared reflections from the anterior ocular surfaces (photo-electro-oculography).[12]

Infrared devices, such as the Ober2 system, are most commonly used in clinical environments. Using the Ober2, eye movements can be tracked during a variety of tasks including reading.[a] The system consists of goggles containing infrared optics and circuitry required to determine eye positions, an electronics

package that digitizes the analog signals from the goggles, and IBM compatible software to analyze the eye movement data.

Reading Analysis Programs

Two programs are used by the Ober2 for assessing eye movements and reading levels. The first (Ober2 Orbital IR Scanning Program, Version 1.33, XY Advanced) gathers data on eye movements made during reading and displays representations of these movements in a graphical format. The second program (Analysis of Eye Movements During Reading, Version 5.3, June 1993) analyzes the data gathered by the first program and provides information on several characteristics of the subject's reading ability. These include 1) the number of fixations per 100 words (sometimes called the decoding level), 2) the mean span of recognition (the average number of words between successive fixations), 3) the number of regressions (how many significant eye movements the subject made to the left) per 100 words, 4) the mean duration of fixations, 5) the subject's reading rate, and 6) the overall reading level. Each of these values is reported as a raw score and a school grade equivalent. Grade equivalents are derived from data collected by Taylor during a norming study.[a,10]

Project Goals

The Ober2 system has great potential for the analysis of eye movement anomalies that become manifest during reading. However, the system has been somewhat problematic to use because of its frequent failures to analyze data and possibly unreliable results. For these reasons, an evaluation of the Ober2 Model B-1200 system and its associated reading analysis programs has been conducted.

This evaluation was done by having the system analyze data produced when 10 standard Taylor paragraphs were read by 62 normal subjects during two sessions.[11]

The project had three goals: 1) to determine how often the system was able to analyze data from 10 Taylor paragraphs, 2) to compare the eye movement data from each of the paragraphs, and 3) to determine the reliability of eye movement analyses by comparing data from two sessions.

SUBJECTS

Two groups of subjects participated in this project. The first consisted of 42 optometry college students. Mean age was 26.7 years (SD=5.4); 22 were males and 20 were females. The second consisted of 20 junior high students. Mean age was 13.7 years (SD=1.0); 10 were males and 10 were females.

All subjects reported that they were normal readers and none had ever been diagnosed as dyslexic or reading disabled. Beyond normal reading ability, the only other criterion for participation was that each subject had at least 6/6 (20/20) best corrected visual acuity at 40 cm.

The college students received course credit for participating in the study; junior high students were not compensated. All subjects or their parents gave informed consent prior to participation.

METHODS

Following an orientation to the Ober2 system, each subject was comfortably seated 40 cm from a text holder inclined back at an angle of approximately 30 degrees from vertical. Goggles were

adjusted for the subject's interpupillary distance, and any lenses required to achieve a minimum of 6/6 (20/20) near acuity were placed in cells on the goggles. Room illumination consisted of a 60 watt incandescent bulb in a desk lamp indirectly illuminating the text holder from a distance of 1.5 meter. A chin rest was used to stabilize the subject's head during reading.

Reading material consisted of Taylor level 7 paragraphs for junior high subjects and level 10 paragraphs for college subjects. The paragraphs were typed double spaced on white paper using 12 point Times bold font and displayed one at a time in the same order for each subject. Paragraph names and reference numbers used for identification are shown in Table 1. Information about these paragraphs (line lengths, etc.) was supplied to the Ober2 system using a program called Create Stimuli Ver 0.6 provided by Harris Associates.[a]

INSERT TABLE 1 ABOUT HERE

To reduce fatigue and to allow determination of split-half reliabilities, data were obtained in two sessions separated by 4 to 5 weeks. The first 5 paragraphs were presented during the initial session, and the last 5 were presented during the second session.

Ober2 analysis normally takes place in two stages. First, the data gathering program records eye movements made during reading and presents a graphical representation of these movements. Then the reading analysis program produces and displays the subject's reading scores. However, for numerous paragraphs, problems

occurred during the process. Attempting leave the data gathering program and enter the analysis program resulted in an error message from the computer[b] and a termination of processing. This created a significant level of frustration associated with the use of the system.

An attempt was made to use the manual calibration routine built into the data gathering program as an aid in processing eye movement data by the analysis program. Manual calibration involves searching for and specifying a subset of the paragraph data representing a single line of text with clean eye movement traces. The manual calibration process was used with data from 25 paragraphs that could not otherwise be analyzed.

RESULTS

The results from this project address questions in three areas: 1) the ability of the program to analyze data from paragraphs and the effects of manual calibration on these analyses, 2) the significance of differences in grade equivalent scores for the 10 Taylor paragraphs read by each subject, and 3) the reliability of grade equivalent scores measured during the two testing sessions.

Analysis of Paragraph Data

Table 2 presents the number of paragraphs that could be analyzed by the Ober2 for college and junior high subjects. The system was able to analyze at least 9 out of 10 paragraphs for about half of the college subjects, but it also failed to analyze at least half of the paragraphs for about a quarter of them.

For the junior high students, the system analyzed data from at least 9 out of 10 paragraphs for only a quarter of the subjects, and

failed to analyze more than 5 out of 10 paragraphs for nearly half of them.

As shown on Table 3, there was no particular pattern associated with which paragraphs were analyzed most often, except that the last two paragraphs read during the second session (paragraphs 9 and 10) had the lowest probabilities of analysis. This might suggest a fatigue effect, but no such effect was seen for paragraphs 4 and 5 which were read last during the initial session.

INSERT TABLES 2 AND 3 ABOUT HERE

Reliability of Data Analysis

Data were selected from 5 randomly chosen college subjects for whom the Ober2 analyzed all 10 paragraphs. Stored data from these 50 paragraphs were re-analyzed by again using the reading analysis program. In every case the values were identical to those produced by the initial analysis. Given the same input data, the output from the reading analysis program was totally reliable.

Effects of Manual Calibration on Program Output

To assess the effects of manual calibration on output from the reading analysis program, stored data from the 50 paragraphs used to assess reliability were again used. Each paragraph was analyzed three separate times using the manual calibration option with different paragraph lines used for each analysis. In every case the results were identical to those produced when the paragraph was analyzed initially. Using the data gathering program's manual

calibration option had no effect on the output from the reading analysis program.

Effects of Manual Calibration on the Ability to Analyze Data

An attempt was made to use the manual calibration option to aid in the analysis of data from paragraphs that could not be analyzed initially (i.e., attempts at analysis produced error messages). Stored data from 25 such paragraphs were selected at random from the data produced by 8 college subjects for whom at least half of the paragraphs could be analyzed (i.e., these subjects did not have problems that totally prevented any analysis of their data).

Three attempts, each using different calibration lines, were made to analyze these data; all 75 attempts failed and error massages were produced. If the data from a paragraph could not be analyzed on the first attempt, using the data gathering program's manual calibration option did not make subsequent analysis possible.

Reliability of Paragraph-by-Paragraph Analyses

To assess the degree to which the reading analysis program returned similar values for each of the Taylor paragraphs, data from the 16 college subjects for whom all 10 paragraphs could be analyzed were considered. (Data from all 10 paragraphs could be analyzed for only 4 of the 20 junior high subjects; their data were not included in this evaluation.)

For every paragraph, the reading analysis program gave exactly the same grade equivalent scores for three different variables: 1) number of fixations, 2) span of recognition, and 3) overall grade level. Because all three scores were identical, the grade equivalent

score for the number of fixations was arbitrarily selected to represent these three redundant values. Mean grade equivalents, standard deviations, and 95% confidence limits of the mean for each of the 10 Taylor paragraphs read by the 16 college subjects are shown on Table 4. Also shown are accuracy data for 10 Taylor comprehension questions that were asked after each paragraph had been read.

Insert Table 4 About Here

Note that for fixations there is a 2.9 grade level difference between mean values for paragraphs 4 and 6 (statistically significant at the 0.05 level by analysis of variance and at the 0.10 level by post hoc Scheffe testing[13]). Depending on which of the Taylor paragraphs was used for testing, this difference could have had considerable consequences for a subject's reading evaluation.

As compared to the other paragraphs, paragraph 4 also produced low mean regression and reading rate scores, but the mean fixation duration score for this paragraph is in the middle of the range for the other paragraphs.

Overall Differences in Grade Equivalent Scores

An analysis of variance was used to determine if there were significant differences between mean grade equivalent scores for fixations, regressions, durations, and reading rates when data were averaged across all subjects and paragraphs (e.g., was the overall mean grade equivalent for fixations significantly higher or lower than the overall mean grade equivalent for fixations?).

Averaged across all 10 paragraphs that were read by the 16 subjects, the mean grade equivalent for fixations was 9.7 (SD = 2.5), for regressions it was 10.3 (SD = 2.5), for durations it was 7.7 (SD = 3.5), and for reading rate the mean was 8.9 (SD = 2.4). The mean regression versus duration difference of 2.5 grades is statistically significant (analysis of variance $p < 0.05$, Scheffe $p < 0.10$[13]). This 2.5 grade difference is also significant clinically and suggests that caution would be appropriate when comparing regression versus duration grade equivalent scores for college subjects.

Split-Half Reliability

Because the data from the paragraphs were gathered in two separate sessions, split-half reliabilities could be determined for the 5 paragraphs read in the first session versus the 5 read in the second session. This was done by using data from the 16 college subjects for whom all 10 paragraphs could be analyzed. Split-half reliability coefficients[14] for the grade equivalents were 0.90 for fixations, 0.84 for regressions, 0.95 for durations, and 0.91 for reading rates. These relatively high values indicate that grade equivalent scores for fixations, regressions, durations, and rates reliably assess the subjects' eye movements made while reading.

CONCLUSIONS

The goals of this project were to evaluate the usefulness and reliability of the Ober2 reading analysis system by considering 1) problems associated with the analyses of reading data, 2) comparability of data from the 10 Taylor paragraphs read by each subject, and 3) comparability of data obtained during the two sessions.

With respect to analysis, the Ober2 failed to analyze data from 30 percent of the paragraphs presented. Clinically these failures can be quite frustrating because they waste the time of both patient and doctor, and the system provides no feedback on what went wrong or what to change. Repositioning of the goggles or restarting the system had no effect on its ability to analyze data; nor did use of the manual calibration option with stored data. If the data did not analyze on the first attempt, no method was found to analyze them later. Re-attempting the analysis or using the manual calibration option did not help.

With respect to the paragraph-by-paragraph eye analyses, care must be taken when interpreting small changes in performance. For example, a significantly misleading conclusion could be drawn for many of the college subjects if preliminary testing in a reading enhancement project had been done using paragraph 4 (John Roebling) and post testing was done with paragraph 6 (Clarence Darrow). There would be an artifactual improvement of almost 3 grade levels in fixation grade equivalent scores if this were done.

Even with these problems, however, the split-half reliability coefficients from the two sessions suggest that when it works, the Ober2 system and Taylor paragraphs can provide a relatively reliable way to assess eye movements made during reading.

In theory, the Ober2 system could fill a critical need in optometric practice for an objective eye movement assessment device to be used for diagnosing reading problems and determining the results of therapy. In the future, the Ober2 system will no doubt have improved software and should prove to be very useful for these

purposes. Unfortunately, at present the system is somewhat frustrating to use, and caution is required when interpreting some of the data produced by its analysis programs.

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FOOTNOTES

a. An Ober2 Model B-1200 system with "Ober2 Orbital IR Scanning Program, Version 1.33, XY Advanced" and "Analysis of Eye Movements During Reading Version 5.3, June 1993" software supplied by Harris Associates (16 Green Meadow Dr., Suite 103, Timonium MD 21093), and an IBM compatible 486 computer were used in this project. More information on the Ober2 system is available from Permobile Meditech Inc., 6B Gill Street, Woburn MA 01801. This system should not be confused with the Ober2 Visagraph (available from Taylor Associates, 200-2E Second Street, Huntington Station, NY 11746), which was not evaluated in this study. An evaluation study on the Visagraph is currently in progress.

b. The following error message was associated with a failure to analyze data: "Runtime error 201 at 4183:0626 has been detected. Please read the diagnostic file TRXDO983.DG. Please send it together with the problematic data to Permobile Meditech AB."

TABLE 1. NAMES OF TAYLOR PARAGRAPHS AND ASSOCIATED PARAGRAPH NUMBERS USED FOR REFERENCE

Paragraph Reference Number	College Paragraph Names (Taylor Level 10)	Jr. High Paragraph Names (Taylor Level 7)
1	Admunsen	Samuel Colt
2	Houdini	Cyrus Field
3	Braille	Clarence Birdseye
4	John Roebling	Elias Howe
5	Dorothea Dix	John Holland
6	Clarence Darrow	Cyrus McCormick
7	Paganini	George Westinghouse
8	Frank Lloyd Wright	Eli Whitney
9	Sir Ernest Shackleton	John Ericsson
10	Clara Barton	Alexander Graham Bell

TABLE 2. NUMBERS AND PERCENTAGES OF THE 10 PARAGRAPHS THAT WERE ANALYZED BY THE OBER2 SYSTEM

Number of Paragraphs Analyzed	Number of College Subjects (Total N=42)	Percentage of College Subjects	Number of Jr. High Subjects (Total N=20)	Percentage of Jr. High Subjects
10	16	38.1	4	20.0
9	6	14.3	1	5.0
8	4	9.5	1	5.0
7	4	9.5	2	10.0
6	2	4.8	3	15.0
5	5	11.9	4	20.0
4	2	4.8	0	0.0
3	0	0.0	0	0.0
2	1	2.4	2	10.0
1	0	0.0	2	10.0
0	2	4.8	1	5.0

TABLE 3. PERCENTAGE OF TIMES DATA FROM EACH PARAGRAPH COULD BE ANALYZED

(Note that the paragraph numbers correspond to different paragraph titles for college versus junior high subjects. See Table 1 for paragraph names.)

Paragraph Reference Number	Percentage Analyzed For College Subjects	Percentage Analyzed For Jr. High Subjects
1	76%	70%
2	81%	60%
3	76%	55%
4	81%	65%
5	81%	60%
6	71%	60%
7	79%	50%
8	83%	70%
9	69%	35%
10	67%	50%

TABLE 4. SUMMARY DATA FROM 16 COLLEGE SUBJECTS FOR WHOM ALL 10 PARAGRAPHS COULD BE ANALYZED

	Number of Fixations		Number of Regressions		Mean Duration of Fixations		Reading Rate		Percentage of Comprehension Questions Answered Correctly	
Paragraph Reference Number	Mean and Standard Deviation	Lower and Upper Confidence Limits	Mean and Standard Deviation	Lower and Upper 95% Confidence Limits	Mean and Standard Deviation	Lower and Upper 95% Confidence Limits	Mean and Standard Deviation	Lower and Upper 95% Confidence Limits	Mean and Standard Deviation	Lower and Upper 95% Confidence Limits
1	10.5 (3.1)	8.9/12.2	10.3 (3.4)	8.5/12.1	7.2 (4.7)	4.8/9.8	9.7 (3.6)	7.7/11.6	79 (15)	71/87
2	9.5 (3.1)	7.8/11.1	9.9 (4.2)	7.6/12.1	6.5 (4.5)	4.1/8.9	8.9 (2.6)	7.5/10.3	84 (11)	78/89
3	9.9 (2.8)	8.4/11.4	9.8 (3.1)	8.1/11.4	8.6 (4.2)	6.3/10.8	8.9 (2.7)	7.5/10.3	78 (14)	71/86
4	8.0 (3.3)	6.2/9.8	7.8 (3.3)	6.0/9.6	7.3 (4.4)	5.0/9.7	7.3 (2.6)	5.9/8.7	85 (9)	81/90
5	8.7 (3.1)	7.1/10.3	8.8 (3.0)	7.2/10.3	6.5 (4.8)	4.0/9.1	7.8 (2.7)	6.3/9.1	77 (13)	70/84
6	10.9 (3.0)	9.3/12.5	12.2 (3.0)	10.6/13.8	6.9 (4.7)	4.4/9.4	10.2 (2.7)	8.7/11.6	74 (12)	68/80
7	9.6 (3.1)	8.0/11.3	10.6 (3.1)	9.0/12.3	8.5 (4.3)	6.2/10.7	8.7 (2.7)	7.2/10.1	84 (8)	80/88
8	10.3 (3.3)	8.5/12.1	11.5 (3.5)	9.6/13.3	8.9 (4.5)	6.5/11.3	9.5 (3.0)	7.9/11.1	88 (7)	84/92
9	9.5 (2.9)	8.0/11.1	11.3 (3.4)	9.5/13.1	8.5 (4.6)	6.0/10.9	9.0 (3.3)	7.26/10.7	82 (9)	77/86
10	9.7 (2.8)	8.24/11.2	10.7 (3.5)	8.9/12.6	7.8 (4.9)	5.2/10.4	9.1 (2.8)	7.6/10.6	86 (12)	80/92