The Reliability of Reading Efficiency Measures Obtained by Classroom Educators Using a Low-Cost Eye Movement Recording System

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Background

The Visagraph is a low-cost portable eye movement recording system that uses goggles fitted with infrared emitters and sensors to measure corneal reflections at a sampling rate 60 Hz (Taylor, 2009). The system is used by schools, clinics, and vision specialists to track eye-movement behavior during reading and to assess silent reading efficiency. In previous research (Spichtig, Vorstius, Greene, & Radach, 2009), recordings obtained using the Visagraph yielded measures of reading rate, progressive saccade counts, and fixation durations that aligned well with those obtained using a more sophisticated EyeLink2K® eye movement recording system.

Figure 1. Student reading text from a normed test booklet while eye movements were recorded using the Visagraph.

Aims

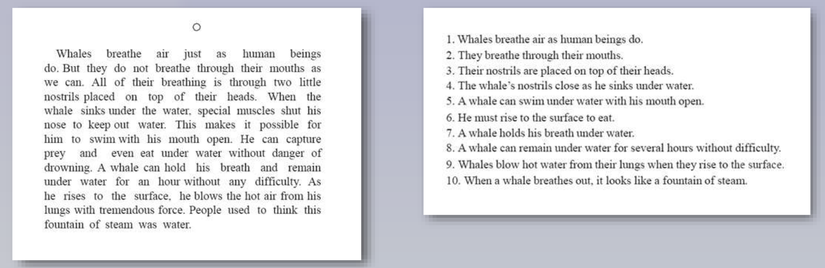
This research examined the test-retest reliability of the Visagraph when used by classroom educators to measure silent reading efficiency in students ranging from second to twelfth grade (approximately 7 to 18 years old).

Method

Data Collection

Recordings were collected by educators while students wore the Visagraph goggles and read standardized passages from a normed test booklet. Each passage comprised 12 lines of text containing about 120 words. The Visagraph software automatically discards data from the first and last lines to minimize anomalies resulting from starting and ending a passage. Analyses are based on data from the middle 10 lines, which contain 100 words.

Students read one practice passage followed by four additional passages with a level of text complexity that matched the student's grade level. Each passage was followed by 10 true/false comprehension questions. Eye movement data were recorded and processed automatically by the Visagraph software.



Whales breathe air just as human beings do. But they do not breathe through their mouths as we can. All of their breathing is through two little nostrils placed on top of their heads. When the whale sinks under the water, special muscles shut his nose to keep out water. This makes it possible for him to swim with his mouth open. He can capture prey and even eat under water without danger of drowning. A whale can hold his breath and remain under water for an hour without any difficulty. As he rises to the surface, he blows the hot air from his lungs with tremendous force. People used to think this fountain of steam was water.

1. Whales breathe air as human beings do.
2. They breathe through their mouths.
3. Their nostrils are placed on top of their heads.
4. The whale's nostrils close as he sinks under water.
5. A whale can swim under water with his mouth open.
6. He must rise to the surface to eat.
7. A whale holds his breath under water.
8. A whale can remain under water for several hours without difficulty.
9. Whales blow hot water from their lungs when they rise to the surface.
10. When a whale breathes out, it looks like a fountain of steam.

Figure 2. Example of a typical Visagraph passage (Left) and a typical true/false comprehension check (Right).

Measures

Measures included silent reading rate (words per minute; wpm), number of fixations per 100 words, number of short-range regressions (up to about 15 letters) per 100 words, and average fixation duration. Grade level norms for these measures have been established (Spichtig et al., 2016). Due to limitations of the Visagraph system, the fixation duration times reported here include saccade time (approximately 20-40 ms), and the regression counts do not include long-range regressions (which typically account for < 3% of regressive saccades; Vitu & McConkie, 2000).

Analyses

Analyses were based on 827 students who completed at least two valid recordings; i.e., recordings were interpretable, line counts matched the text, and a comprehension criterion was met (70%). Because this comprehension criterion was used, all reported reading efficiency measures are referred to as being "comprehension-based." Using data from the first two valid recordings, test-retest reliability coefficients and coefficients of variation (CV%; e.g., Lexell & Downham, 2005) were calculated for reading rate, fixations, regressions, and fixation durations. The CV% was calculated as the square root of the mean square error (RMSE; from the repeated measures analyses of variance) divided by the means of the valid recordings.

Results

Mean values for each measure closely matched reading efficiency norms reported previously (Spichtig et al., 2016). Across all measures, reliability was lowest in grades 2-4. In grades 6 and above, reliability coefficients averaged .86 for reading rate and .80 for fixations, with CVs between 9% and 11%. Measures of fixation duration had lower CVs, averaging 7.1% in grades 6 and above, while regressions in these grades had the highest CVs, averaging 27.6% (see Figure 3 and Table 1).

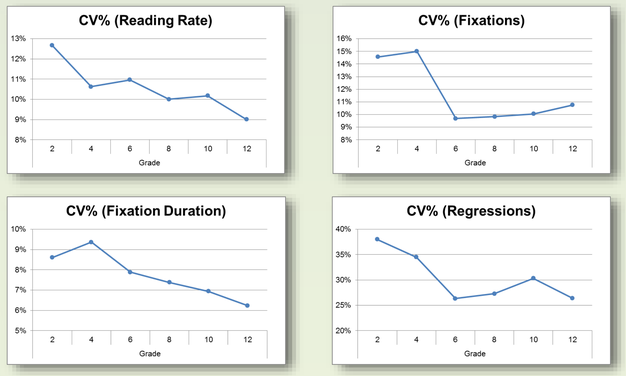


Figure 3. Coefficients of variation across grades for each of the four reading efficiency measures.

Table 1. Relative and Absolute Indices of Reliability for Four Reading Efficiency Measures across Grades.

Grade	2	4	6	8	10	12
n	95	127	135	219	118	133
Reading Rate (wpm)						
Mean	129.3	157.8	171.4	174.7	190.7	198.5
SEM	16.4	16.8	18.8	17.5	19.4	17.9
r	0.87	0.83	0.85	0.86	0.83	0.90
CV%	12.7%	10.6%	11.0%	10.0%	10.2%	9.0%
Fixations per 100 Words						
Mean	167.0	135.9	131.9	134.8	123.2	126.1
SEM	24.3	20.4	12.8	13.3	12.4	13.6
r	0.67	0.51	0.80	0.82	0.75	0.81
CV%	14.6%	15.0%	9.7%	9.8%	10.1%	10.8%
Regressions per 100 Words						
Mean	27.3	23.1	21.2	22.8	17.5	19.0
SEM	10.4	8.0	5.6	6.2	5.3	5.0
r	0.60	0.52	0.77	0.79	0.71	0.83
CV%	38.0%	34.5%	26.3%	27.3%	30.3%	26.4%
Fixation Durations (ms)						
Mean	313	316	297	286	282	269
SEM	26.9	29.6	23.4	21.1	19.5	16.8
r	0.78	0.65	0.70	0.80	0.79	0.80
CV%	8.61%	9.37%	7.88%	7.38%	6.94%	6.24%

Conclusions

Educators and researchers with an interest in reading-related eye movement behavior face many sources of variance. One is the inherent variability of reading behavior, which research has shown (e.g., McConkie, et al., 1991), and the present results confirm, is greater in children who are still learning to read. Additional variance arises from variations in text complexity and their interaction with an individual's level of reading proficiency. As well, there is variance associated with the limitations of the eye movement recording system. All of these factors contribute to the reliability of eye movement recordings. The present results provide estimates of measurement reliability at different grade levels using the Visagraph – data that can be useful when designing experiments (e.g., selecting sample size) and evaluating results.

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