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Eye movements of students with learning disabilities in reading: A study of problem solving strategies

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Abstract

In this exploratory study, eye movements of students with and without a learning disability in reading were recorded as they solved a set of third grade science problems. The recorded eye-gaze information included location of eye-gaze fixation on a computer screen, duration of fixation, the path of eye movement, and duration between fixations. The results revealed statistically significant differences in latent response time, question-zone fixation time, total fixations and correct responses.

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Keywords: eye gaze; reading disability; problem solving; fixation

1. Introduction

Federal legislation, such as the Individuals with Disabilities Act (IDEA) and No Child Left Behind (NCLB), has mandated that students with disabilities be given access to the same grade level content and standards, despite their independent reading level or reading ability. Individual state standards, high school exit exams and standardized tests are becoming increasingly difficult and rigorous, especially within the area of language arts. Therefore, the requirements for grade level completion and graduation is problematic for those students who are not reading and comprehending material that is at their grade level.

Even though some students with learning disabilities experience difficulty with reading, they are being tested more and more with formal and informal standards based assessments. These tests are given to all students and are used to evaluate the progress of schools, districts, counties, states and the nation. To truly assess our students, however, educators must focus more on the reliability of these testing materials and the validity of data that it provides. Educators and researchers also need to create alternative assessments that will yield results that can be used to plan instruction for students with reading problems more effectively.

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Most of the formal and informal paper and pencil tests used to assess reading achievement produce results that indicate if a student has answered a question correctly or incorrectly. Beyond this, we are left to speculate about the problem-solving strategies and patterns students used to derive their answers. What if we were able to observe what students were doing (specifically, what they were looking at?) while solving problems? The use of the eye-gaze tracking device may provide an avenue to provide more in-depth knowledge about students' problem-solving patterns. According to Pavlidis (1985), tracking eye movements is one method that can be used to reveal and understand the process involved in the reader's behavior. The illustration of eye movement data can be used to pinpoint the specific problems of the reader. For example, unlike a paper and pencil reading comprehension test that reveals if the child with a reading disability (RD) chose the right answer for each individual question, studying eye movement allows researchers and practitioners to observe if a child read all of the passage, or if a child carefully looked at the answer choices given for the particular problem. By obtaining a "mapping" of a child's eye fixation on a reading passage, researchers can find which word or parts of the text attracted a child's attention or were the most difficult (Pavlidis, 1985).

With eye-gaze tracking devices, researchers can also collect data about the location and duration of an eye fixation within a specific area on a computer monitor. When objects such as words and pictures are shown on the display, an individual's eye-gaze may be tracked as they look at these words and pictures. Based on the location of eye fixations, inferences may be drawn regarding the activity and intent of a student (e.g. focusing more on the pictures than reading the text before answering a question). Therefore, knowing if a child has read the text or rereads the text multiple times to comprehend while solving a problem may reveal reading patterns that can be used to create more efficacious instructional strategies.

The purpose of this study was to determine if differences existed between the eye movements of students with reading disabilities (RD) and students without reading disabilities (non-RD) when solving Virginia Standards of Learning (SOL) science questions. We wanted to glean a broader understanding of student thinking during the problem solving process. In addition, we wanted to determine if results would yield information that could be used to inform assessment and reading instruction for RD students. Therefore, we addressed the following research questions in this study: (a) Are there eye movement pattern differences between the two groups when solving science SOL questions? If so, how do these patterns differ? and (b) Are there differences in fixations and saccades while solving problems between two groups of students?

2. Method

2.1. Participants and setting

Twenty-eight students from two rural elementary schools in Virginia agreed to participate in this study. Of the 28 students in this analysis, 54% (n = 15) were general education students and were not identified as having a reading disability (non-RD) and 46% (n = 13) were diagnosed with learning disabilities in reading (RD) based on criteria established by the state of Virginia in accordance with guidelines set forth by the IDEA. Forty-six percent of the students were male (n= 13) and 54% were female (n= 15).

The overall ethnic background of students was 61% White (n=17), 35% African American (n=10), and 4% Asian American (n=1). In the group with RD students, there were 33% (n=5) African American, 60% White (n=9) and 7% Asian American (n=1) student and for the non-RD group, there were 38% African American (n=5) and 62% White students (n=8).

2.2. Materials

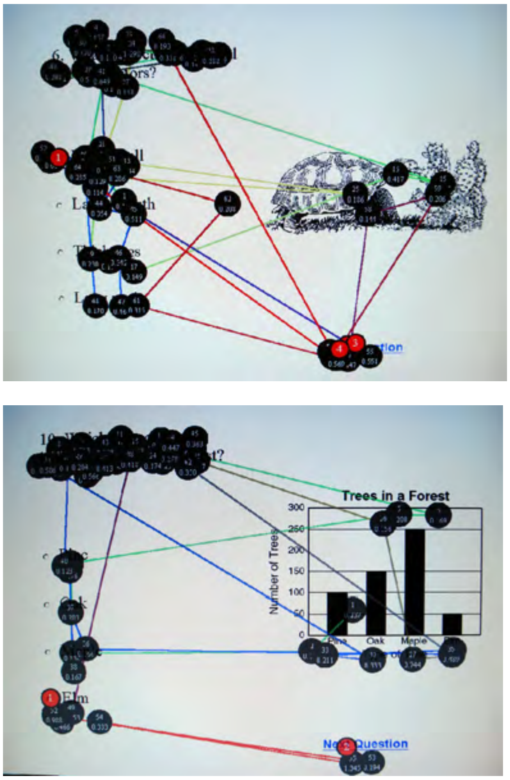
Participants in the study completed an assessment that contained 17 multiple-choice science questions. Each item in the assessment was composed of four elements: (a) the text of a question or question stem, (b) an image (a graph, an illustration, or a table/chart), (c) the answer as well as three distracters, and (d) a hyperlink to advance to the next question. Each subsequent question was presented in an identical manner. For example, the location of the image, question, answer selection, and the hyperlink to the next question were all located in the same place for each question. This consistency in the layout minimized simple orientation eye-movements of the user to the screen.

2.3. Measures

Four types of data were collected during the measurement of eye movements: eye fixation location, fixation durations, saccades, and saccadic length. The definition of these terms is based on a comprehensive review of literature compiled by Rayner (1998). An eye fixation is the period in which the eye remains relatively still allowing visual information to be collected (Rayner, 1998). Fixation duration, typically measured in milliseconds (ms), represents the amount of time that an eye remains fixated. Saccades are the eye-movements that occur as an individual reads and/or examines and object or scene. Due to the speed of movement of the eye during a saccade, no visual information can be collected (Rayner, 1998). In Figure 1, the black dots in the figure covering various elements represent the location of eye fixations while the lines connecting successive fixations represent saccades.

Non-RD

RD



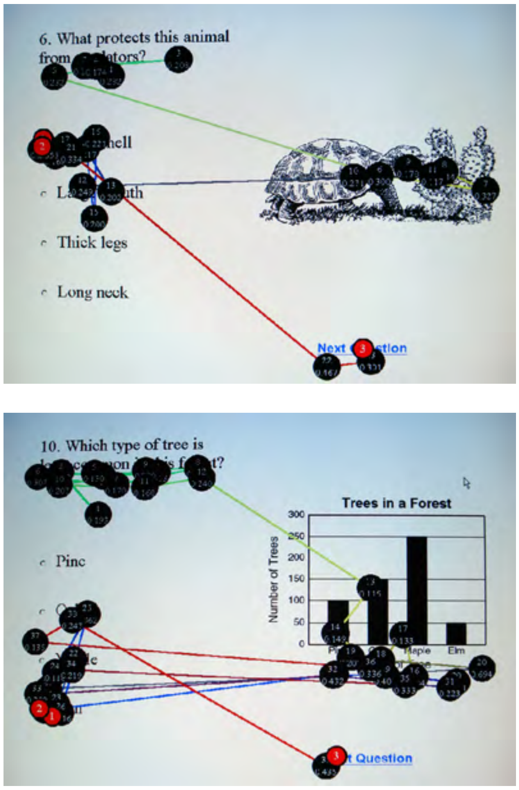


Figure 1: Fixation map

Using analysis of variance, we compared the differences between response time, fixation time and initial reading of question time to see if there were statistically significant differences between non-RD and RD students. In addition, differences in fixation time on question zone versus image zone were compared to determine which group favored questions more than image or vice versa.

3. Results

3.1. Quantitative analysis

An analysis of variance (ANOVA) was used to determine if there were significant differences between the two groups. Table 1 presents the analysis of quantitative data using the following comparisons: (a) mean and standard deviation comparison of correct responses, (b) comparison of latent response time, (c) comparison of total time in Question Zone (Q-Zone), (d) comparison of total time in Image Zone (I-Zone), (e) total fixation comparison, and (f) total Q-Zone fixation comparison. All six variables were presented with effect sizes and five variables had F-values. The effect sizes were calculated using Cohen's D equation (d = MEANA – MEANB / SD pooled) and the effect size values were interpreted with the strength scale.

Table 1. Descriptive statistics, F-value, and effect size for dependent variables

	Non-RD Students (n=15)		RD Students (n=13)			
Variable	M	(SD)	M	(SD)	F	ES
Correct Responses	12.88	(2.47)	10.82	(2.83)		.78
Latent Response Time	17.37	(3.78)	23.56	(6.95)	8.92**	1.11
Q-Zone Time	4.40	(1.56)	7.07	(2.64)	10.96**	1.23
I-Zone Time	5.11	(1.02)	5.44	(1.63)	.42	.24
Total Fixation	43.64	(10.97)	51.60	(14.89)	2.64	.61
Q-Zone Fixation	13.53	(6.27)	17.88	(6.27)	4.68*	.81

4. Discussion

In this study, several measurements used showed statistically significant differences between the RD and non-RD groups answering the second research question posed earlier. Some of the stronger significant results were seen in comparison of latent response time, total Q-zone fixation time and fixation mappings. Using the analyses and the concepts from the diagram mentioned above, we discuss the visual attention comparison between the two groups.

First, we address the first research question: Are there eye movement pattern differences between the two groups when solving science SOL questions? If so, how do these patterns differ? In their book on eye movement study, Paulson and Freeman (2003) stated that eye movement recording produced a map of the reader's reading process including millisecond-by millisecond data of what the reader did such as skipping a word, going back to the previous sentence, and how long the reader looks at one area. Along the same lines as Paulson and Freeman, we documented what a child was looking at during an assessment session. These data document the path, duration, and density of students' eye movement actions that other assessment tools may not be able to provide.

The eye movement mappings of non-RD students showed less clustering in the eye movement maps and a lower number of saccades. This could be because the non-RD students possessed more knowledge about the content being tested, but this speculation is questionable since there were no significant differences between the two groups on correctly answering the questions. The data showed that among all 17 questions only one question had statistical significance in terms of frequency of non-RD students answering the question correctly. Hence, and as we indicated in the previous section, another hypothesis could be that students with RD might have different patterns that may be less efficient than non-RD students when they are engaged in problem solving. For example, in this study RD students spent more time solving the problems and also they spent more time in the question zone. Other researchers have found similar findings. Eden, Stein, Wood, and Wood’s (1995) study compared the performance of non-disabled readers (NR) and individuals with RD on phonological and visual tests and found that the RD group's performance was significantly poorer than the NR group on several visual and eye movement tests.

In addition to having a different eye movement patterns, we found that more RD students were starting their problems in the Image or Answer Zones rather than the Question Zone. The usual pattern would be for students to read the question before looking at other parts of the problem, but interestingly, more RD students looked at other zones first. This eye movement behaviour was not obvious in comparing all 28 students in this study; but overall, more RD students did start in the zone outside of the Question Zone. Why would RD students start their problem-solving pattern in a zone other than the Q-Zone? A possible answer may be that students with RD are relying more on the information given in the Image or Answer Zone. The deficit in reading ability may have caused RD students to rely more on the information presented, not in words, but in illustrations. Once again, another factor that may explain this eye movement behaviour could be the lack of metacognitive skills that the RD students possess. The ability to search and predict answers, creating questions about the problem, and self-questioning during the test are some of the skills that RD students might be lacking. These are skills that can help students in understanding the question completely before moving to the illustration section of the problem or predicting an answer before moving on to the answer zone. Helping RD students in learning the metacognitive skills such as taking conscious control of learning, planning and selecting strategies, monitoring the progress of learning, correcting errors, analysing the effectiveness of learning strategies, and changing learning behaviours may result in eye movement patterns that are more efficient (Ridley, Schutz, Glanz, & Weinstein, 1992). In addition to the strategies mentioned above, RD students may benefit from instant feedback on their problem solving process. After each problem set, an instructor can interview the students to determine if they can articulate the strategies used to solve the problem. This process may provide more meaningful understanding of student’s problem solving strategies.

5. Implications

With eye-gaze tracking devices becoming more accessible and affordable, this technology in education should be more widely used. Eye movements are a powerful method for observing and understanding the process involved in the reader’s behaviour (Pavlidis, 1985). Unlike most other assessment tools, eye movement data can be used to pinpoint the specific problems of students while they are solving a problem. For example, most assessments only provide information about the end result, whether or not the student answered the questions correctly. However, eye-movement mapping provides information about what the student was actually doing during the problem-solving process. This provides an overall picture of problem-solving strategies exhibited by the student that can be used to develop more powerful interventions. In combination with traditional assessments and instruction, data prepared from eye-movements, interviews, and think aloud may help teachers develop interventions that are more directly linked to the actual problems that students experience when engaged in problem solving. The more students know about their own problem-solving skills and are taught more efficient ones, the more likely their performance will improve. The overarching goal for this process would be to inform students about their personal problem-solving methods and to guide them in changing certain inefficient behaviours and developing metacognitive strategies that are more efficient.

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