iRead Interface

A study on eye tracking integration of future E-readers

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Abstract

Eye movements provide a rich and informative window into a person's thoughts and intentions. In recent years researchers have increasingly employed eye movements to study cognition in psychological experiments, to understand behavior in user interfaces, and even control computers through eye-based input devices. (Salvucci 1999) The patent application for 'Using gaze actions to interact with a display' by Slavko Milekic was the basis and starting off point for this project. His invention relates generally to user interfaces for interacting with objects in a display and more particularly to user interfaces in which eye movement is used to control a pointing device and thereby to interact with the objects in the display. (Milekic p.) iRead Interface developed from the ideas and principals stated in his patent along with vast research on eye-tracking, learning disabilities and the cognitive process of reading. This paper is a summary of the development process of a project that suggests digital readers be integrated with eye-tracking technology as a means of improving reading speed and cognition.

1. Introduction

Our eyes reveal a great deal about us; whether or not our eyes are "windows to the soul" as the common saying goes, they are certainly windows to our mind. Eyesight is simply the ability to see something clearly, the so-called 20/20 eyesight as measured in a standard eye examination Snellen chart. Vision goes beyond eyesight and can best be defined as the understanding of what is seen. Vision involves the ability to take incoming visual information, process that information and obtain meaning from it. (Getz 1973) Reading, like vision, is a learned brain process that includes numerous cognitive steps. At a minimum, these processes include the visual processes that are necessary to encode the individual words from the printed page, the cognitive processes that are necessary to retrieve the pronunciations and meanings of these words from memory and then use this information to construct the meaning of the text, and the motor skills that are necessary to program and execute the eye movements that move the eyes from one word to the next. (Reichle 1998)

Studying eye movements in a well-defined task like reading, allows a better understanding of the "eye-mind link," or how cognition interacts with perception, on one hand, and motor control, on the other. People that suffer from learning disabilities or are poor readers may have eyesight problems such as: visual acuity, adequate convergence or binocular coordination, but rather typically the problem lies within the brains cognitive organization of what is seen. The focus of iRead Interface is directed towards assisting poor readers by using modern eye tracking technology to bridge the gap between the learning disabled and skilled readers.

1.1 History

For hundreds of years scientists have studied the connection between eye movements and thoughts during the task of reading. (Just & Carpenter, 1980, 1984; Schilling, Rayner, & Chumbley, 1998) In 1879, University of Paris Professor Emile Javal observed that a reader's eyes do not sweep smoothly across print but instead rapidly jump from one point to another, making short stops called eye fixations. The jumping motions he called saccades. (Paulson and Goodman 1999) With the acknowledgment that the eye does indeed stop at certain places along a line of print came the basis for exploring the role of eye movement in reading. One of Javal's colleagues at the University of Paris, Landolt, provided the first concrete insight into the reading process made possible by eye-movement research in 1891. Landolt provided the first evidence that the eyes do not precede on a regular, predetermined path, but vary depending on the type of reading being done. Study of their movements therefore provides a window to the cognitive processes of perception and comprehension that take place during reading. (Paulson and Goodman 1999)

1.2 Current State of Affairs

Tracking eye movements has been shown to be a diagnostic of the underlying cognitive processes during reading. (Feng 2003) It has become increasingly popular, as new technology becomes more accessible -some requiring no more than a desktop video camera, for the development of eye indicating interfaces to evolve. These developments open exciting possibilities for new applications. In this instance, the monitoring of eye movements of readers provides assistance in real time when the eye movement pattern indicates difficulties in comprehension, just like experienced reading teachers would do based on their assessment of a child's cognitive state. Additional information about a words pronunciation and meaning may be automatically delivered to the screen if eye movements indicate the viewer is confused on a particular word or sentence.

In neurobiology and vision research, researchers have focused on the underlying mechanisms of eye movements and laid a solid foundation for understanding fundamental characteristics of human visual processing. In human-computer interaction, researchers have studied eye movements to better understand interface use and to develop successful eye-driven user interfaces. (Salvucci 1999) Typical eye movement data sets are simply too large and complex to

be analyzed by hand or by automated methods. New classes of algorithms are constantly being developed to provide fast and robust automated analysis of eye movement data. (Salvucci., Goldberg 2000) Mathematical models have become an important tool for understanding the control of eye movements during reading. (Engbert, Nuthmann, Richter, Kliegl 2005) *E-Z Reader* is just one example model that precisely describes the eye movements of skilled readers. This model is a mathematical description of how perception, cognition, and oculomotor factors determine when and where eyes move during reading, and can be used to stimulate the eye-movement behavior of readers. The model also helps validate the use of eye-tracking technology to study cognitive processes during reading. (Pollatsek, A., Reichle, E.D., & Rayner, K., 2006) Text 2.0, Ace-Reader and Confident Reader are all examples of existing interfaces that assist reading, but do not use eye-tracking technology.

2. The Problem

The evolution of learning techniques and education systems in America, as well as most everywhere on the globe, support a left-brained dominant learning style. Standardized tests and school curriculums discriminate against slow readers and suppress creativity. Educational leader and author Ken Robinson boasts, "Intelligence is diverse, dynamic and interactive. Creativity is as important as literacy." He agrees with Picasso that all children are born artists, and as they grow up are educated out of their creativity. Children are taught to read by being read out loud to or by reading out loud to someone else. They pronounce each individual word out in their mind, called sub-vocalization. There is a growing consensus that phonological deficits play a key role in dyslexics' reading problems. Phonological deficits in dyslexia are typically assessed using metalinguistic tasks vulnerable to extraneous factors such as attention and memory. Eye movements of dyslexic children were monitored and tracked to measure phonologically related items. Desroches, A.S., Jooanisse, M.F., Robertson, E.K., (2006). Additional reading difficulties are found in students with visual tracking and eye teaming dysfunction. There are numerous reading interfaces evolving that help teachers educate right-brained learners and poor readers, but they are not widely adopted by, or offered to, the general public. As of now, schools and educators have not accepted what has been scientifically proven about reading and cognition. Different brains should be able to choose different methods for learning that maximize their learning potential and best fit their learning style.

2.1 Learning Disabilities

Today in America twenty five million people are functionally illiterate. Fifteen percent of Americans are dyslexics and prescriptions for ADHD have increased by 500% since 1991. For a term that was hardly known before the 1960's, *learning disability* has come to include everything from unexplained behavior patterns to clinical autism and everything in between. Learning disabilities have emerged as

one of the most wide-ranging medical problems of children who live in developed countries where communicable disease is no longer a major threat. (Pastor, P. N., Reuben, C. A., 2002) Psychosocial problems are the most common chronic condition for pediatric visits, eclipsing asthma and heart disease (Kelleher, K. J., McInerny, T. K., Gardner, W. P., 2000) The National Institutes of Health state that 95 percent of poor readers can be brought up to grade level if they receive effective help early. Dr. Renee Fuller, Ph. D., states that

> "Neuroimaging technologies, instead of showing us the causes of learning pathologies, give us an insight into how different neural organizations are responsible for our different abilities. "learning disability" merely reflects a variation in cognitive organization; that historically these variations have manifested themselves in the diversity of talents that created human culture and laid the groundwork for our industrial society."

Its bad enough that reading, writing and language are difficult for right-brained individuals, but its worse that our culture still embraces the traditional educational system that suppresses, labels and prescribes drugs to these people.

2.2 Left and Right Brain Processing

It was only in 1981 that Dr. Roger Wolcott Sperry won a Nobel Prize for discovering that our brains of are of two minds. He found out that the human brain has specialized functions on the right and the left, and that the two sides can operate partially independently. Reading, writing and language are functions of the left-brain hemispheres. In addition to thinking in a linear manner, the left-brain processes in sequence. It processes from part to whole. It takes the pieces, lines them up and arranges them in logical order; then draws conclusions. For example, spelling involves sequencing- if you are left-brained; you are probably a good speller. The right brain however, processes from whole to its parts, holistically. It sees the big picture first, not the details. The right brain contains visualization and creativity.

In western cultures, reading is done from left to right. Research done by Stephen Christman, a pschologist at the University of Toledo, Ohio, concluded that leftward eye movements activate right brain functions and rightward movements activate left-brain functions. His research also suggests that horizontal eye movements improve memory by helping right and left functions interact. He has also shown that certain eye movements improve recall memory.

Learning and thinking are enhanced when both sides of the brain participate in a balanced manner. Educational focus should be on strengthening the corpus collosum and bridging the gap between the left and right. It is important for people to know and understand their learning style so that they can work to strengthen their weaker side. Eye tracking exercises are currently used to strengthen peripheral vision and enhance reading experiences for speed readers.

2.3 Speed Reading

Dr. Kawamura, developer of the EyeQ program found that we can significantly increase our brains learning and processing ability through a series of high-speed imaging exercises which utilize both graphics and text. He also found that our brains can be stimulated and improved by using techniques that push us out of our comfort zone. Dr. Kawamuras vision therapy and eye-training sessions strengthen the eyes and increase peripheral vision, allowing us to take in more material at once. The imaging engages more of our right brain, of the creative part of our brain. The high-speed imaging stimulates the neuro pathways, strengthening the eye-brain connection and improving our thinking and reaction time. His research revels that skilled readers display three major differences over novice or poor readers: The first is fixation time, how long we look at a word before moving to the next. The second, fixation span is how many letters our brain processes at a time. And the third is regression, is how often we look back and reread what we have already read. Regression reflects that skilled readers reread material only 10-15% of the time verses up to 50% for novice of poor readers. Speed reading engages both the left and right hemispheres equally because readers visualize scenes about what they are reading instead of sounding out words and lining them up in sequence to derive meaning.

2.3 The way we read

We have the knowledge and technology, especially through neuro imaging and eye tracking to diagnose and assist those currently mislabeled with disabilities. We know that reading and language are left-brain process and that nearly every person struggling to read is a right-brain learner and most always are the same ones diagnosed with learning and behavioral diseases such as dyslexia and ADHD. Neither hemisphere dominate learner is more intellectual than the other, just simply different. Their abilities are merely organized in a different ways just as the pigment of blue-eyed people is organized in a different way from that of brown eyed people. Never will two brains read exactly the same, yet reading is homogenized task. Learning to read is critical to a child's overall well being. (Lyon 2000) The sad realization is that people struggling to read have a high chance of becoming scholastically disinterested. The catorgized 'special education' students in school feel and are taught as though they aren't smart and are less capable than their left-brained peers.

3. Solution

The future of how we read is constantly evolving. Why shouldn't the way we read? Digital reading continually increases as the printed word decreases. The economic benefits of digital readers continue to rise. They continue to become more and more affordable, as well as convenient, especially for students. Programs like 'one lap top

for every child' are extremely popular and prove that a universal educational tool is in the horizon. As eye-tracking technology becomes more affordable and integrated into society, the studies and ideals on its capabilities will increase with it.

3.1 iRead E-reader interfaces

iRead interfaces are eye-tracking technology integrated e-readers. They would diagnose visual and comprehension problems people have while reading as well as stimulate and test people with attention and behavioral disorders. An eye-tracking digital reader such as iRead Interface could adjust various modes of text delivery based on someone's eye movements and learning preferences. It would not only be intuitive and anamorphous, it would learn things about the user and store data to better inform students and teachers about the users particular learning style, speed and focus.

3.2 Interactivity and Scaffolding

Electronic readers allow people to interact with texts in ways they cannot with the printed word. An iRead interface would encourage people to read and help them become better readers. If the methods in which we receive information had evolved to far, why wouldn't the nature or the task? Using eye-tracking technology, iReader's would know when a user was fatigued, distracted, or cognitively overloaded. It could then adjust text modes depending on the users preference or cognitive condition. By collecting important information such as the users reading speed, or words per page and words most often regressed, readers are kept better informed about how they read and where they need to put in extra work. The ultimate goal of iRead is to afford the same learning experience for all individuals, even those with severe disabilities. It aims to end the traditional practices and beliefs that poor readers are disabled and not just different. Whether it be teaching a user to speed read or simply enlarging and scrolling text for a user with vision and eye teaming problems, iRead aims at creating epistemic user actions- physical actions that make mental computation easier, faster or more reliable. (Kirsh, D., Maglio, P., 2008) Scaffolding exists naturally within the interface. If a particular mode stops working while in use, by graceful degradation the interface simply runs as all e-readers do currently, without eye tracking assistance.

Many people are slow readers without being classified 'learning disabled.' These people could improve their speed and comprehension by controlling their eye movements with iRead Interface. Different interactive text modes that assists readers would include:

Flash mode delivers words one at a time. This eliminates negative shapes created by typical text that can be distracting for dyslectics and right-brain readers. Users can set the speed, size and position of text to their preference.
Highlight mode acts as a highlighting finger that travels just in front of the eyes natural movements. A slight highlight appearing just in front of the users eyes helps

maintain focus and speed. People are encouraged to use their finger as a courser while reading because it helps keep their place and sets a desired pace. iRead can improve your reading speed by increasing the speed of the highlighter to slightly challenge your eye movements.
Hypertext mode allows the user to adjust the density of hypertext within a body of text. Because right brain learners are holistic they benefit from scanning articles before they read them. Hypertext not only affords graceful scanning but also helps to control unnecessary eye movements and assists speed readers.
Regression mode allows the user to set their desired amount of assistance on confusing words. Regression patterns can indicate to the interface when supplemental information such as pronunciation and meaning are necessary. Aid may come in the form of audio or a pop up window.
Scroll mode moves text to your eyes instead of your eyes to text. This process eliminates unnecessary eye movements as well as automatically turns pages.
Visual mode adds imagery to text in order to increase recall memory and assist right-brain learners. Right brain dominant learners are better at created scenes in their head as opposed to sub-vocalizing words in sequential order to obtain meaning. This mode is ideal if a user prefers to learn to speed read.
Zoom mode is ideal for not only learning disabled, but also the elderly and users with eyesight problems. Zoom enlarges text intuitively based on eye movements. The user can adjust the delivery of text to zoom from word to word, or by line, sentence or paragraph.

Multiple modes may co-exsist if necessary and desired by the user. iRead interface aims at having limitless options of customizing itself to a user.

4.2 Users

iRead interface would help bridge the communication gap between the minds cognitive load and the educators delivery of information.

iRead Interface aims to try and change that. The idea behind *iRead Interface* is that all brains are created equal.

4.3 Design Affordances

5. Further Development

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