Learner Behavior Analysis through Eye Tracking

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Abstract
In e-learning, it is necessary to create more effective interaction between the educational content and learners. In particular, increasing motivation by stimulating learners' interest is very important. Users' eyes can be a significant source of information to analyze learner behavior. What we look at, and how we do that, can be exploited to improve the learning process. Eye tracking is the process of measuring either the point of gaze ("where we are looking") or the motion of an eye relative to the head. An eye tracker is a device for measuring eye positions and eye movement. This paper introduces the use of eye tracking technology to track and analyze the learners' behavior on an e-learning platform. Specifically, interesting areas of the course for each learner and also the learner's emotions like level of attention, stress, relaxation, problem solving and tiredness.

Keywords: E-Learning, eye tracking, eye movement, gaze tracking, learner profiling, learner behavior.

Introduction
In a virtual learning environment, learners can lose motivation and concentration easily, especially in a platform that is not tailored to their needs. Our research is based on studying learner's behavior on an online learning platform to create a system able to clustering learners based on their behavior, and adapting educational content to their needs. Eye movements provide an indication of learner interest and focus of attention. They provide useful feedback to personalize learning interactions, and this can bring back some of the human functionality of a teacher. With a study of eye movement, learners may be more motivated, and may find learning more fun.

Eye tracking technology
Eye Tracking Methods
Many different methods have been used to track eye movements since the use of eye tracking technology was first pioneered in reading research over 100 years ago [7]:
- Electro-oculographic method (EOG): Relied on electrodes mounted on the skin around the eye that could measure differences in electric potential induced by eye rotation (Fenn & Hursh, 1934) [11].
- Scleral search coils method: This technique required the wearing of large contact lenses that covered the cornea (the clear membrane covering the front of the eye) and sclera (the white of the eye that is seen from the outside).
- Corneal-reflection method: Most commercial eye-tracking systems available today measure point-of-regard by the "corneal-
reflection/pupil-centre” method. These kinds of trackers usually consist of a standard computer with an infrared camera mounted beneath a display monitor, with image processing software to locate and identify the features of the eye used for tracking. In operation, infrared light from an LED (Light-Emitting Diode) embedded in the infrared camera is first directed into the eye to create strong reflections in target eye features to make them easier to track (infrared light is used to avoid dazzling the user with visible light). The light enters the retina and a large proportion of it is reflected back, making the pupil appear as a bright, well defined disc (known as the bright pupil effect). The corneal reflection (or first Purkinje image) is also generated by the infrared light, appearing as a small, but sharp, glint [7].

Once the image processing software has identified the centre of the pupil and the location of the corneal reflection, the vector between them is measured, and, with further trigonometric calculations, point-of-regard can be found. Although it is possible to determine approximate point-of-regard by the corneal reflection alone by tracking both features eye movements can, critically, be disassociated from head movements [7].

Eye-Movement Metrics
Eye movement is typically divided into fixations and saccades, fixation is the moment when the eyes are relatively stationary, taking in or encoding information, and saccade is an eye movement occurring between fixations, typically lasting for 20 to 35 milliseconds. The purpose of most saccades is to move the eyes to the next viewing position. Visual processing is automatically suppressed during saccades to avoid blurring of the visual image. Most information from the eye is made available during a fixation, but not during a saccade.

The resulting series of fixations and saccades is called a scanpath. Scanpaths are useful for analyzing cognitive intent, interest, and salience. Other biological factors (some as simple as gender) may affect the scanpath as well. Eye tracking in human-computer interaction studies typically investigates the scanpath for usability purposes, or as a method of input in gaze-contingent displays, also known as gaze-based interfaces.

Eye Tracking VS Gaze Tracking
Eye trackers necessarily measure the rotation of the eye with respect to the measuring system. If the measuring system is head mounted, as with EOG, then eye-in-head angles are measured. If the measuring system is table mounted, as with sclera search coils or table mounted camera (remote) systems then gaze angles are measured.

In many applications, the head position is fixed using a bite bar, a forehead support or something similar, so that eye position and gaze are the same. In other cases, the head is free to move, and head movement is measured with systems such as magnetic or video based head trackers.

For head-mounted trackers, head position and direction are added to eye-in-head direction to determine gaze direction. For table-mounted systems, such as search coils, head direction is subtracted from gaze direction to determine eye-in-head position.
Using An Eye Tracker
After attaching a camera, the application starts by detecting the pupil, however, we can select it manually. First, we must configure the tracking engine; most eye trackers contain two types of tracking: pupil tracking and glint tracking, you can also activate both at the same time.

Video-based eye trackers need to be fine-tuned to the particularities of each person’s eye movements by a calibration process. This calibration works by displaying a dot on the screen, and if the eye fixates for longer than a certain threshold time and within a certain area, the system records that pupil-centre/corneal-reflection relationship as corresponding to a specific x,y coordinate on the screen. This is repeated over a 9 to 13 point grid-pattern to gain an accurate calibration over the whole screen.

Finally, you can configure the software to redirect the mouse cursor to the gaze position, or display a new cursor for tracking.

Eye Tracking in E-learning
Applications that use eye tracking can be categorized as either diagnostic or interactive. Diagnostic applications show where the learner's attention has been caught, thus providing evidence of the learner's focus of attention over time. In the interactive type, the eye movements are used to replace an input system, such as mouse, allowing the user to interact with a computer using only the eyes [1].

Learner's Emotion Tracking
The data collected from eye-tracking devices indicates the person's interest level and focus of attention. From eye position tracking and indirect measures, such as fixation numbers and duration, gaze position, and blink rate, it is possible to draw information about the user's level of attention, stress, relaxation, problem solving, successfulness in learning, tiredness, and more. Even emotions can be tracked, and based on the data; the eye-tracking system can provide more personalized learning [1].

For example, if the average pupil size has progressively increased within a certain time interval, also user workload may have augmented. A decreased blink rate in the same period would further confirm such a supposition. When detected, such evidences could for example be used to dynamically modify the learning path, proposing a topic related to the main one but less complex (a sort of break). Or, if the user is potentially having problems in understanding something, extra information may be displayed.

Since several external factors may come into play, however, it is practically impossible to be absolutely sure that these signals derive from changes in the user emotional state. Therefore, rather than undertaking direct actions, such as displaying help windows, the system can assist the user indirectly with gradual assistances. For example, when signs of non-understanding or high mental workload are detected, the system simply proposes links to additional material, which progressively enlarge as the signals of stress persist. When eye data suggest that the user may be tired, and the session has been going on for more than a configurable time interval (e.g. one hour), a message advising to take a break is shown [3].

And here are some experimental evidence in psychology / physiology:
- Mental workload depends on the fluctuation of the rhythm of the pupil area.
- Saccade occurrence rate and saccade length decrease with increased complexity of the task.
- Saccadic and blink velocity decrease with increasing tiredness.

**Learner's Interest Tracking**

We can track learner's interest according to his eye movement on an online learning platform. In this example, we used a free Eye Tracker "Gazetracker 2.0 Beta", and we have activated the "Eye mouse" option to redirect the mouse cursor to the gaze position. We can use any eye tracker provided that it supports the "Eye mouse".

The web page is divided into several areas "<div>" , each div contains a different type of information of the same chapter and we will calculate the time spent by the learner on each div by tracking the mouse cursor. To do this, we use two Javascript events: onMouseOver and onMouseOut, whenever the cursor enters a div, it starts a timer that calculates the time in milliseconds, and it stops when the cursor leaves the div or when user leaves the entire page, using setInterval() and clearInterval() functions. When the cursor enters again the same div, the timer continues where it stopped last time.

![Figure 5. Web page divided into 4 areas to track learner's interest](image)

Tracking data will be stored in the database; teachers can find the gaze duration statistics of each area and for each learner. We converted the durations from millisecond to second to make them easier to understand.

**Table 1. Gaze duration statistics**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner 1</td>
<td>210.22 sec</td>
<td>73.40 sec</td>
<td>43.05 sec</td>
<td>165.25 sec</td>
<td>491.92 sec</td>
</tr>
<tr>
<td>Learner 2</td>
<td>144.12 sec</td>
<td>124.67 sec</td>
<td>29.87 sec</td>
<td>170.45 sec</td>
<td>469.11 sec</td>
</tr>
<tr>
<td>Learner 3</td>
<td>243.49 sec</td>
<td>142.32 sec</td>
<td>12.01 sec</td>
<td>98.71 sec</td>
<td>496.53 sec</td>
</tr>
<tr>
<td>Div Total</td>
<td>597.83 sec</td>
<td>340.39 sec</td>
<td>84.93 sec</td>
<td>434.41 sec</td>
<td>---</td>
</tr>
</tbody>
</table>
Further analysis on the learner profile such as learning style, tiredness, confusion can also be performed once the data are set. For example a learner with a strong visual memory but weaker verbal processing will spend more time on the picture rather than the text. Once the learner’s learning method is identified, the educational content is adapted to provide mainly images and video, rather than text, and thus increasing the efficiency of the learning process.

When learner logs in, the results from the parameters analysis block are saved in the database. Every time when the user starts a course, his behavior is recorded in the database. This includes when the course is started, which page the learner had visited and how long she/he spends on each area. This data is combined with eye movement to get a fine-grained user profile.

**Conclusion**

We talked in our first paper about using learner personal data, and his statistics of interaction with the system and the available educational tools (quiz, forum, wiki, chat…), and also using data from the client’s machine extracted from web server to analyze learner behavior. In this paper, we introduce the use of eye tracking technology for the same purpose.

Eye-movement analysis does appear to be a promising new tool for evaluating learners’ behavior. This technology can provide many benefits to e-learning, such as facilitating adaptive and personalized learning. Even though the cost of an advanced eye tracking system is still high, in a couple of years the rapid technical progress may come with low-cost solutions and accurate eye tracking systems.

**References**


