Eye-Tracking Analysis of Computer Networks Exam Question Besides Different Skilled Groups

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***Abstract*— The article presents an eye tracking analysis based study in context of learning IT skills. The goal of eye tracking analysis is to determine the gaze movement differences between students with different prior knowledge during answering a question in the topic of computer networks. The gaze movement was tracked by cost-effective Eye Tribe tracker, and the eye movement data was evaluated by Ogama software. Examinations were organized as a student's project using the methodology of project-based learning. The study shows that differences can be detected in eye movement parameters of students with different prior knowledge, in the number and duration of fixations and length of saccades.**

Keywords—eye-tracking; learning; Eye Tribe

I. INTRODUCTION

Eye tracking analysis helps understanding cognitive functions. With an eye tracking system, by monitoring eye movement data, human attention can be examined (Fig. 1). [1][2] Eye movement is a main part of cognitive functions, because we can receive visual stimuli with our eyes, which are later processed by our brain. So actually visual attention initiates ('activates') cognitive functions, which are essential in solving a task. [3] Applying systems based on eye tracking on different fields, may accelerate researches and make them more efficient. In order to create such systems, movement and parameters of human eyes shall be studied first, which has a relatively long history. Researches tracking human eyes started right in the beginning of the 1900s. By the development of science and technology, several more efficient methods were elaborated in the past century, which were capable of performing more accurate examinations decade-by-decade. Development of technology enabled involvement of newer tools, which helped making research methods more efficient. In the beginning, necessary conclusions were made only by the light reflecting from the cornea, later horizontal and vertical movement of eye were also taken into consideration (Buswell). In later decades of the century, more complex studies were common, where during view of pictures and paintings, then commercials, different saccadic movements, fixations were studied. By the spread of Internet, several studies were dealing with fields watched by the user by surfing web sites: which are those partial fields by watching a website, where the attention of user is longer in time. Using results of studies, optimal layout of websites could be defined, regarding human attention. Studies seemed to be so efficient and representative, that one of the biggest commercial and marketing agencies of the world, EURO RSCG also applied this method. Nowadays, along with the already applied tools (EOG, contact lens working with special infrared lights), technologies based on visual process are spreading.

Human activity, visual attention can be measured from the parameters of eye movement, which even the human emotional condition can be figured out from. This Human – Computer interaction actually detects a cognitive action of a human that makes sense under Cognitive Infocommunications [18], [19]. That's why a system based on eye tracking can be also well-used in studying efficiency of learning processes. Recently, more have been performing such studies. Calvi and others have examined human behavior inside the e5learning project, when processing different e-learning contents. [4] Eye tracking are also applied in several fields of studies related to learning. Porta evaluated eye movement data of students in an experiment studying learning experiences, where examination of learning experiences was made with the help of adaptive system. [5] Pivec educed a monitoring framework inside ADELE project, whose goal was tracking view of students at dynamic process of e-learning contents. [6] Hyskykari's iDict project assessed the needs of students by tracking their view. [7] Such development has been also introduced by Wei and his team for virtual learning environments. [8] Wang developed such a software agent, which sustained students attention using emotional reactions. [9] Porta also educed a system, which changes of students emotional conditions have been checked with, based on parameters of eye movement. [10] Drewes introduces a system in his study, which it can be also tracked with, in what order and extent users read text parts in web browser. With the help of JavaScript code embedded into HTML code of virtual learning environment, real-time percentage values became detected regarding intensity of text reading. The goal of the study is defining a visual indicator regarding how the reading process helped students in learning. The study shows that eye movement data can be used for enhancing efficiency of learning, however authors also note that already used adaptive systems are still limited in their functions, while only small part of learning conditions can be examined with them. [11] Schmidt-Weigand examined in a study the relation of text and image contents in

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a multimedia learning material. Based on eye movement data of nine students, he showed that visual dispersion of learning environment was basically text-driven.

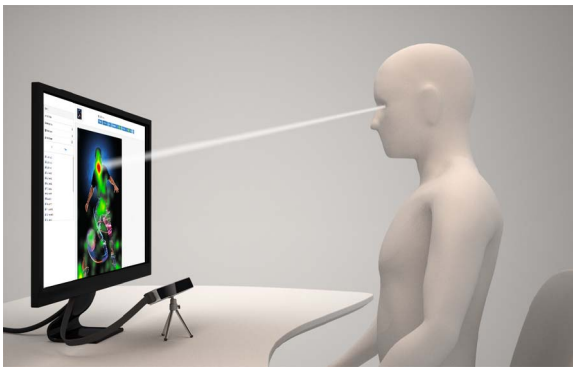

Fig. 1. Eye tracking with screen-based eye tracker

In contrary, visual elements defined visual attention of students, when voice replaced written text. [12] Study of Al-Wabil showed, that students of different learning styles (visual/verbal) showed different visual behavior during learning. The study revealed, that verbal students focus mainly on text content, while visual types observe only some parts of the text (spending a short period of time on the selected parts) and focus more on multimedia contents. [13] Tsianos made a similar study, and compared eye movement data of different learning styled students in a hypermedia-based learning environment. [14]

II. EYE-TRACKING METRICS

Human eye is one of the basic elements of mechanisms processing information received from our environment. As referred above, with our eye, reception of different visual stimuli becomes available, then we process them with our brain. In controlling eye movement, a complex neurological background is necessary. Motoric operation of vision system is realized with the help of eye muscles. Moving eyeballs can be performed intentionally, by moving them to the area of interest, and keeping in the field of view by series of spontaneous movements. Basically there are two types of moves: fixations and saccadic moves (Fig. 2).

Fixation: focusing to a defined point, where the view lasts longer. Average fixation length is between 100-1000 ms, in most cases this period of time is 200-500 ms. Period of time mainly depends on the quantity of information to be processed, and the actual cognitive strain. Fixations designate the condition of eye, when eyeball stands still, and receiving or 'decoding' of information are performed. Different index numbers can be derived from fixations, such as the length and number of fixations, place of first fixation, time passed until first fixation, total length of all fixations, or visual information reception during fixations. [15]

Saccade: also known as regression, designates short, quick and leaping movements between two fixations. Visual search ('scanning') is one of its main determining factors. Average lengths of saccades are between 20-35 ms. It defines the next view position for the eye. If there is a movement exceeding 30°, the head also moves together with the eye. During visual information process, the eye automatically hides all saccades, which would cause blurring of the observed area. Indices may be derived from saccades:

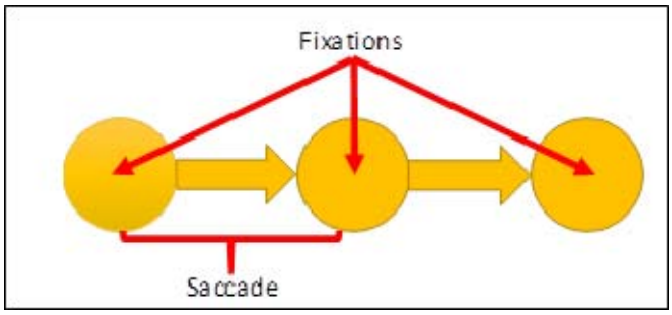

Fig. 2. The difference between fixation and saccade

Length of view: also known as fixation cluster or fixation cycle, 'dwell' If we are talking about length of view, we consider length of all fixations and saccades, regarding the pre-defined, observed area. By analyzing the view, distribution of attention can be measured between target areas. It can be used for a kind of 'forecast': when view remains on a defined point, an event related to, caused by it is likely. (e.g. If the view of subject remains long on a detail or heading when watching a website, he/she will likely click on it.).

III. EYE-TRACKING ANALYSIS

The goal of eye-tracking analysis is to show, what kind of differences –related to eye moves- can be showed between student groups with different prior knowledge when solving a task regarding IT problems. Performation of the examination happened by involving testing subjects with IT background, who had to answer a question related to computer networks, while their eye moves were being observed. Tracking eye moves were performed by Eye Tribe tracker, evaluation of data related to eye movements were performed by Ogama software. Before performing the examination, testing subjects filled out a theoretic test, and by their results, they had been put into three groups: Lower than average (LTA), Average (A), Better than average (BTA).

A. The Eye Tribe

Eye Tribe tracker is a video-based, handheld eye tracking tool, which the direction of view can be defined with, and measures can be performed regarding parameters of eye moves. The device works with infrared (NIR) detection. Tracker is made up by two main parts: a camera, and a high-resolution infrared LED. The camera follows user's eye movements, including finest moves on the pupil. By sophisticated computer algorithms, it is able to read the coordinates, which are then showed by software application. Camera sensors of the device operate between even different light conditions, so enhancing user's experience. The device

operates between 30 and 60 Hz sampling rate, with 0.5° average accuracy and 0.1° (RMS) spatial accuracy. Its operational range is between 45 – 75 cm.

The application possibilities of Eye Tribe tracker in psychological researches is investigated in [17]. The results show that the Eye Tribe can be used in researches despite of low cost.

Fig. 3. The Eye Tribe tracker

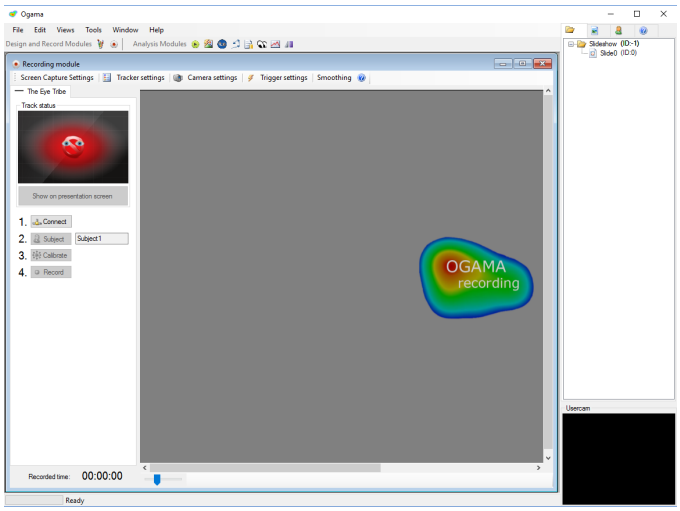

Fig. 4. Recording Module of OGAMA

B. *OGAMA (OpenGazeAndMouseAnalyzer)*

A freeware, open-source software, which enables reception and process of eye moves and mouse moves. The program can cooperate with gaze tracker, talking about target hardware or web camera. Its main features are data-controlled pre-processing, or filtering eye movement and mouse movement. Measured data can be exported, depending on text or module, into video format too. Data can be showed and evaluated in several forms, the program contains more (10) modules accordingly. Modules of the program [16]:

Stimulus Design Module: Here we can create different slides and contents, which we can make different subjects observe.

Record Module: In this module eye movement data can be recorded by observing content showed on screen. Recording data is performed in four steps: when device has to be connected by clicking on 'Connect' button, then record testing subjects data to store them in the database and for eventual statistical representations. Recording data is preceeded by the calibration phase, where following nine accurate calibrations, we can accept that depending on the quality of calibration. Then by clicking on 'Record' button, recording data can be started, which finishes by passing exit conditions set for the presented slide in Design Module (e.g. clicking or expiry of given period of time).

Replay Module: We can replay recorded fixations, by connecting recorded fixations route of view becomes visible.

Attention Map Module (heat map): Based on the number of fixations, distribution of attention can be tracked between each parts of the viewed slide.

Scanpath Module: Route of view is visible, with different visualization modes. We can chose from point, circle, light and attention map (heat map) based visualization forms.

Fixations Module: All parameters of fixations can be analysed. In tabular form, number, length, recorded X and Y coordinates can be presented. The module presents fixations graphically as well, in the way presented in Scanpath module.

Saliency Module: It is intended to calculate the salient locations on the stimulus images. It uses the bottom up saliency model from the ilab toolkit from Prof. Laurent Itti. It can predict the scanpath and calculate saliency maps.

Statistics Module: Following calculations from recorded eye movement data, further data can be received regarding fixations, saccades, views and move of mouse.

Areas Of Interest (AOI) Module: Separate areas can be defined on the slide to be observed, which can be then examined one-by-one.

C. *Student's project*

The study of eye-tracking analysis described in next chapter was organized as a student project during a semester. The project was organized taking into account the Project Based Learning (PBL) methodology. The knowledge of theoretical background and methods of eye-tracking was learnt in the first four weeks, and then the students learnt how to use the Eye Tribe tracker and Ogama software. After learning the Ogama modules, some basic eye-tracking tests and analysises were performed, and in the last four weeks, the study examinations and data were carried out.

D. *Study*

During performing the examination, testing subjects had to answer a question regarding computer networks (Fig. 5), while their eye movements were observed by using Eye Tribe tool. The question to be answered appeared on the computer's screen, on the slide presented by Recording Module of Ogama software. Prior to the examination, calibration processes were performed in all cases, which the proper detection ability of eye tracking system could be controlled with. Recording eye movement data started from the appearance of the slide containing the question, until the testing subject selected the answer thought to be correct. Post-procession of data was performed after finishing the tests. The examination was

performed by involving 15 testing subjects with IT knowledge. Distribution of testing subjects regarding sex: 13 males and 2 females. Regarding their age, they were all between 20 and 50. Prior to the test, (computer network) knowledge of subjects had been evaluated, and their classification into group had been performed. According to the test results, 7 persons were put into the group of average skills, 5 could be put into the Lower than average group, while 3 into the Better than average group.

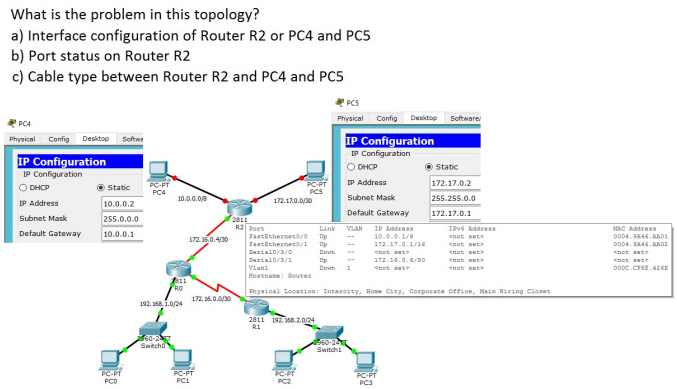

Fig. 5. Exam Question of the Study

IV. RESULTS

Thanks to the statistic module of Ogama software, some main parameters of eye movement were defined; whose results are shown in the first table:

TABLE I. EYE METRICS RESULTS OF EXAM TEST

Subjects' skill	Eye Metrics Results of Exam Test				
	Fixations (count)	*Fixations (count/s)*	*Fixation Duration Mean (ms)*	*Fixation/Saccade ratio*	*Avg. Saccade Length (px)*
LTA*	305	1,76	281	494	235
A**	245	2,15	287	617	216
BTA***	190	2,51	305	765	175

* Lower Than Average
** Average
*** Better Than Average

As seen in the table, eye movement parameters of the three – with different knowledge levels- groups also show differences. The values are average values calculated from members of each groups. In the LTA group, number of fixations are higher (305), than in the A (245) and BTA (190) groups. In contrary, at the mean values of fixation lengths, inverse relationship is experienced: members of BTA group provided higher value (305), compared to the A (287) and LTA (281) groups. Similarity can be experienced between measured number of fixations in the given period, and the fixation/saccades rate. In case of LTA group, the two values are the smallest: 1.76 and 494, while at the A and BTA groups 2.15 and 617, or 2.51 and 765. Average saccade length rate is similar to the case of fixations. Average of LTA group is 235, while A and BTA groups have around 216, and 175 value. You can see an example landscape of visited and unvisited locations on the stimulus image in Fig. 6. In Fig. 7, you can see an example orientation map about the exam test, which shows the salient locations and scan path on the stimulus image. One BTA user's gaze path, fixations and fixation connections are shown in Fig. 8.

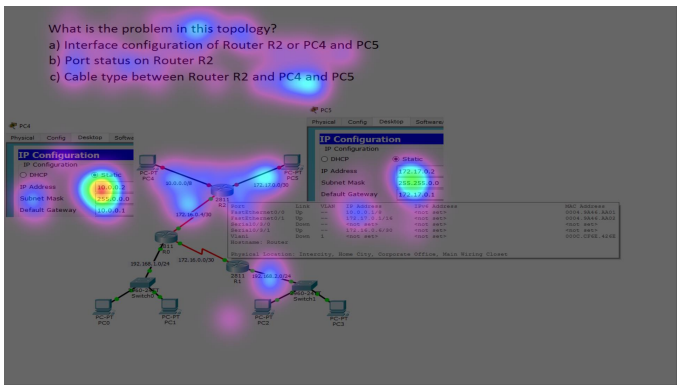

Fig. 6. Attention Map of Gaze

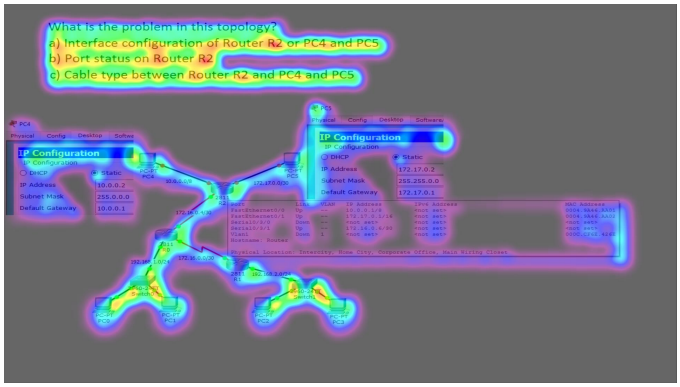

Fig. 7. Orientation Channel of Saliency

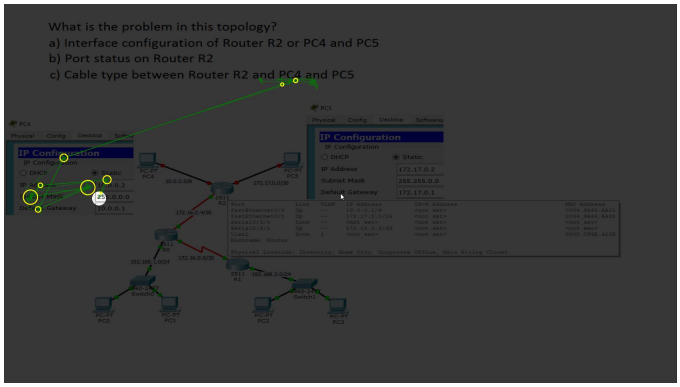

Fig. 8. Gaze path, fixations and connections when one of the users reading the task

V. CONCLUSION

Examination shown in the article has been performed among the previously defined groups. Result of examination showed, that between learning groups with different prior

knowledge – during solving a task related to IT problems-differences can be experienced in parameters describing eye moves. Information received by examining eye moves, can be used to compile the tasks when working out formal and content elements. By an eye tracking system, student's eye movement data can be monitored. Thanks to the data received from observation, conclusions can be made regarding cognitive processes, which can be related to examination of learning efficiency, regarding success or lack of success in learning.

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