Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2013, 33(105) pp. 75–78
ISSN 1733-8670

2013, 33(105) s. 75–78

Using eye tracking data for evaluation and improvement of training process on ship's navigational bridge simulator

Bartosz Muczyński, Maciej Gucma, Mateusz Bilewski, Paweł Zalewski

Maritime University of Szczecin, Faculty of Navigation, Marine Traffic Engineering Centre
70-500 Szczecin, ul. Wały Chrobrego 1–2
e-mail: {b.muczynski;m.gucma;m.bilewski;p.zalewski}@am.szczecin.pl

Key words: eye tracker, gaze data, statistical analysis, mental workload

Abstract

The paper presents basics of the eye tracking methodology and results of preliminary test on multi-purpose marine ship's navigation bridge simulator. The use of the eye-tracker on the navigation bridge makes it possible to objectively measure the ergonomics of the individual interfaces, as well as to evaluate the decision-making process itself, including the mental workload and stress. In the experiment, officers were faced with an unexpected and sudden situation leading to a collision. The simulated situation required the officer to act immediately and resolutely, taking into account all his/her knowledge about the ship, and interpreting the available data correctly. Outcome of this test was compared with gaze data and it was proved that experienced group with best results suffered lowest level of mental workload and was most efficient in decision making process. Based on those results a possibility of improving simulator training with the use of eye tracking data is discussed.

Introduction

Eye-tracking is concerned with methods and techniques used for registering eyes' movements and points of gaze with the use of specially designed equipment – an eye tracker. In one of its most basic form, eye tracker uses one or more cameras to register so called Purkinje images (Fig. 1) or Purkinje reflections and based on this data, calculates Point of Regard (POR). This allows for precise identification of visual scene's elements on which subject focuses his/her attention [1]. Two most important type of eye movements that can be registered with an eye tracker are fixations and saccades.

Fixations are eye movements, lasting for around 200–300 ms, that are stabilizing the retina on a stationary object or area [1] – point of fixation. In neuropsychology fixations are directly related to cognitive processing meaning that during fixation, subject is analyzing and interpreting information from the object or area of focus. This can be directly connected to process of searching required information on the visual scene: fixations shows where and for how long subject focused his/her attention [2].

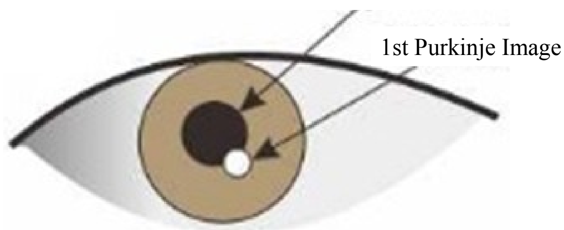

Fig. 1. Purkinje reflection [3]

To analyze fixation data two factors have to be taken into consideration: location of fixations with regard to the visual scene and fixations characteristics (duration time, frequency, quantity, etc.). With such approach it is possible to visualize gathered data in form of so-called Heat maps or Focus maps (Fig. 2). Both includes coordinates and number of fixations but Heat map additionally allows for coding average time of fixation with different colors. Fixations can also be analyzed as a series of events that forms so called Scan path allowing for evaluation of specific task. Fixations are often interpreted as an indicator of mental workload and thus can be used as an objective measure of task's difficulty [3].

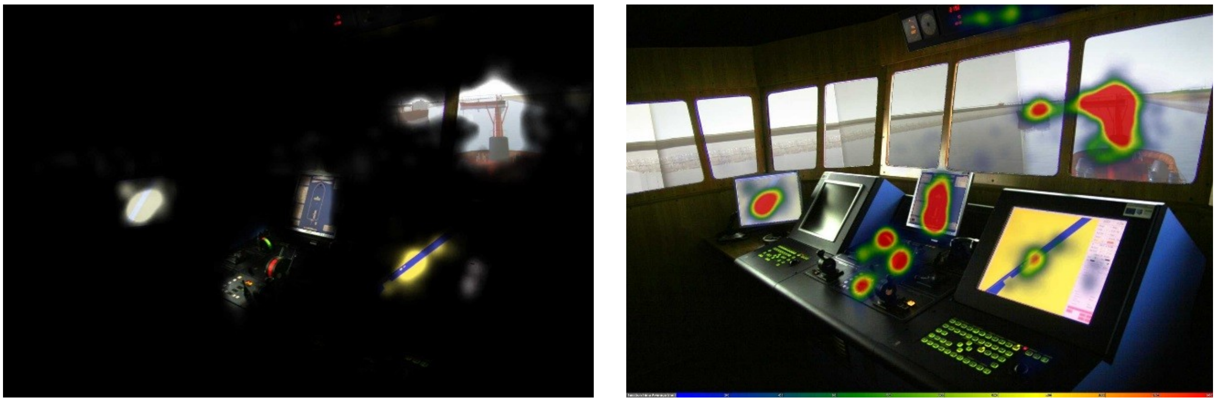

Fig. 2. Focus map (left) and heat map (right) created from eye tracker data

Saccades are rapid eye movements between two fixations, lasting around 10–100 ms, that are connected to changing position of the fovea to another location [1]. Opposite to fixations, saccades are not related directly to cognitive processing – this eye movement is too fast to register and analyze visual information. Having data about number, frequency and duration of a saccadic movement conclusions about proportion of time and effort between process of searching and analyzing specific object in a visual environment can be drawn out. Saccadic movements are also related to higher levels of stress and nervousness [4].

Most of modern eye trackers measure and record much more information about human eye and its movements allowing for even deeper analysis of cognitive processing. Among those, two are valuable as indicators for levels of mental workload, cognitive processing and stress [5]:

1. Pupil diameter;
2. Number, duration and frequency of blinks.

Eye trackers are, in majority, stationary devices suited for registering eye movements on a single screen – a visual environment that itself is stationary, covered by subject's field of vision and does not require any head movements. Such approach could not be implemented on ship's navigational bridge nor in any environment that requires subject to move around and constantly change head position to collect set of data. For this reason a mobile eye tracker was proposed as a best solution for initial tests, specifically Eye-Tracking Glasses (Fig. 3) manufactured by SensoMotoric Instruments (SMI). Aside from being mobile, this particular eye tracker is lightweight and does not restrict nor hamper any head movements. It is recording data with 30 Hz frequency and provides accuracy up to 0.5°. Following data can be obtained:

- Fixations: location, duration, start time;
- Saccades: location of start and end points, duration, start time, velocity;
- Pupil diameter;
- Blinks: duration, start time.

Fig. 3. Eye Tracking Glasses [6]

Experiment proposition

Eye trackers are widely used in cognitive processing researches, human-computer interfaces usability and in marketing (website and advertisement design). Few researchers pointed out usefulness of gaze tracking data in predicting skill-level differences in collaborative tasks [7], assessing situational awareness of VTS's operators [8] and evaluation of interruption modality influence on task resumption [9]. Such approach could be modified and used on the full-mission navigational bridge simulators. Such study could lead to several conclusions:

1. Evaluation of bridge design in ergonomic aspect;
2. Evaluation of radar, ECDIS and conning interfaces in usability and ergonomics aspects;
3. Evaluation of Officer of the Watch situational awareness;
4. Evaluation of differences in decision making process and information analysis between experienced and junior officers;
5. Evaluation of simulator training efficiency.

Based on this a set of experiments is being planned. In its final stage it should be possible to collect and analyze complex data acquired during 4-hours watch in simulated conditions.

During first stage it was planned to test initial hypothesis about differences in eye tracking characteristics between experienced and unexperienced officers. It was also important to develop a method for analysis and interpretation of collected data.

The participants of the experiment included:

- 3 captains, male, of the average age of $m = 51$, $\sigma = 6.2$, with at least 7 years of experience in the position of the captain (group No. 1);
- 4 officers of the watch, male, of the average age of $m = 27.5$, $\sigma = 0.8$, with at least 2 years of experience in the position of the third officer (group No. 2);
- 3 students of the last year of studies, male, of the average age of $m = 21$, each of whom had an independent practice of at least 6 months on marine ships (group No. 3).

None of the participants has any visual impairment, nor wore contact lenses or glasses during the experiment.

The experiment was conducted entirely in the multi-purpose marine ship's navigation bridge simulator in the Marine Traffic Engineering Centre located at the Maritime University of Szczecin, Poland. The simulator works under the Polaris System by Kongsberg Maritime AS, which was granted the certificate of compliance with the international convention of Standards of Training, Certification and Watchkeeping.

For the purpose of this experiment a script of overtaking and bypassing of ships in a narrow canal was created. Three ships took part in the scripted manoeuvre, of which ship A was steered by the examined participant and ships B and C were controlled by simulator. During the manoeuvre, a failure of another ship (ship B) was simulated. The failure made it impossible to bypass or overtake that ship, which in turn forced the officer to immediately bring his ship to halt. An incorrect performance of the manoeuvre led to losing control over the ship, a collision with another ship, or running into the waterfront.

Data analysis

The gaze data analysis was conducted mainly with the BeGaze software by SMI. To analyze data from a visual scene it is necessary to set up so called Areas of Interest (AOI) – specified regions on visual scene for which certain eye tracking characteristics (like number of fixations and dwell time) are calculated. At this moment AOI can be pinned to specified coordinates in relation to subject's field of view, not to certain object. With mobile eye tracker the visual field, and AOIs with it, are changing in time, dependently on officer's head movement. To analyze this part of data it is necessary to use Semantic Gaze Mapping function that allows to copy information about every fixation from video stimulus onto static picture (Fig. 4). This single option allows for creation of heat and focus maps, detailed statistics for every AOI and comparative analysis between single subjects and whole groups. Being essential for every eye tracking experiment of this type it has a distinctive drawback – it is

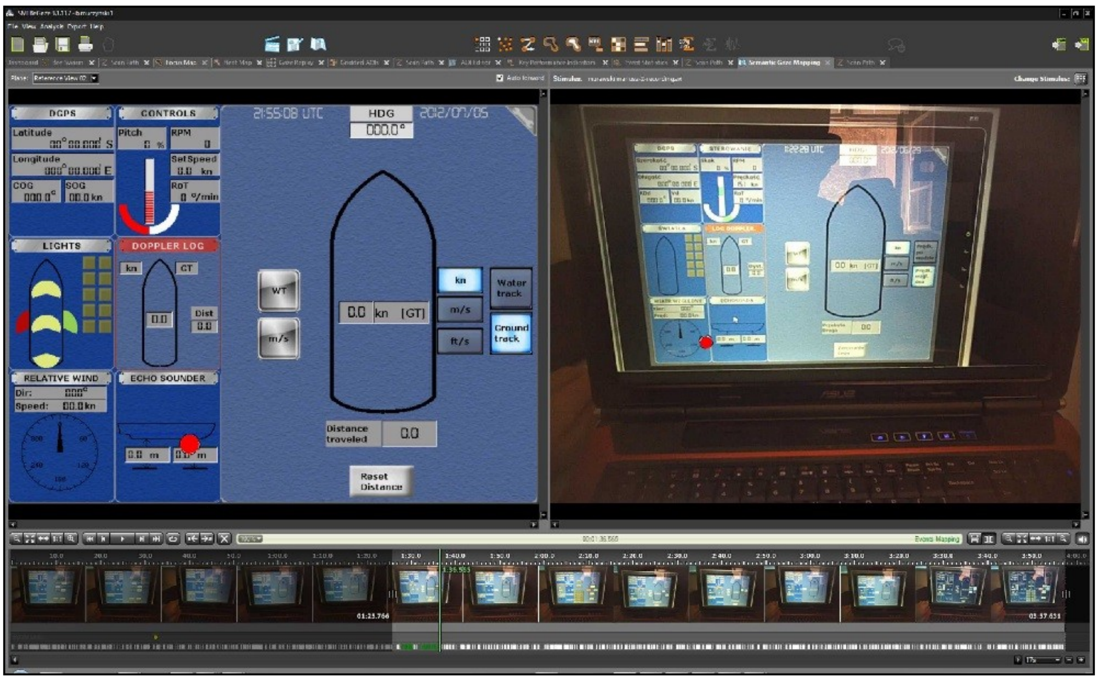

Fig. 4. Sematic Gaze Mapping function. Right side shows recorded video stimulus, left side shows static stimulus – image of tested interface. Red dot on both sides is a recorded fixation point

time-consuming. In described experiment a single trial took around 12 minutes, during which 1500 fixations were registered on average. Mapping such a single trial required 45–60 minutes.

Second part of the analysis was concentrated on statistical and time-series analysis and it was made independently in Microsoft Excel software.

Results

No significant differences were found pertaining to the domains on which the officers of the watch focused their attention. Each of the participants concentrated predominantly on observing the two other ships in the canal, the controls, and the conning display. In the case of the experienced captains, the importance was attached mainly to the visual observation of the position of the three ships and the assessment of the distance between them. Group No. 3 concentrated more on radar screen than two other groups and at the same time had lower fixation count on both ship B and C (Fig. 5).

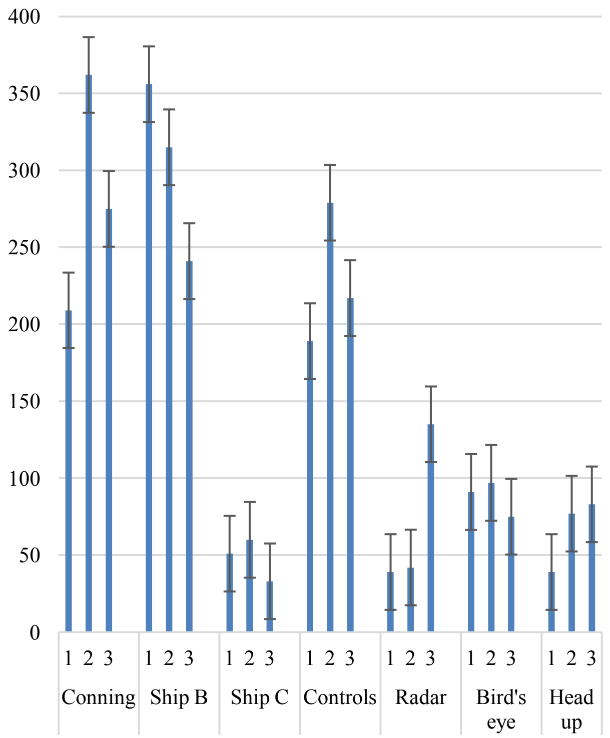

Fig. 5. Fixation count for selected Areas of Interest for groups 1, 2 and 3

The analysis of the average number and frequency of eye fixations and the frequency of saccades and blinking showed that the level of mental workload was the lowest and the ability to interpret data correctly was the highest in group No. 1 (Tab. 1). This group's performance of the manoeuvre was at the same time assessed as the most correct and effective.

Table 1. Basic eye metrics for each group

	Fixations	Fixation fq. $[s^{-1}]$	Saccade fq. $[s^{-1}]$	Blink fq. $[s^{-1}]$
Group 1	1154	2.03	1.7	0.875
Group 2	1731	2.60	2.3	0.950
Group 3	1615	2.33	1.9	1.067

Conclusions

Analysis of the collected data proved that basic eye tracking characteristics, namely number and frequency of fixations, saccades frequency and blinks frequency can be used as an indicator of mental workload that correlates with the correctness of a manoeuvre, its effectiveness and the level of the experience of a participants. It is expected that further experiments will prove that gathered data can be used to improve simulator training by mapping gaze data of unexperienced students and presenting main distractors during standard navigational watch. The results of the experiment should not be treated as final nor as a statistical representation of the general tendencies in the eye movement characteristics for Officers of the Watch. It was designed for limited number of participants and scripted in a way that expected the officer to focus his attention only on the two other ships in the narrow canal.

Further experiments will require a different approach to data analysis, especially in aspect of mapping fixations from video to static stimulus.

References

1. DUCHOWSKI A.T.: Eye Tracking Methodology. Springer, London 2007.
2. EHMKE C., WILSON C.: Identyfying web usability problems from eye tracking data. Proceedings of th 21st British HCI Group Annual Conference on HCI, 2007, 119–128.
3. http://gazeparser.sourceforge.net; 10.03.2013
4. HOLMQVIST K., NYSTROM M., ANDERSON R., DEWHURST R., JARODZKA H., VAN DE WEIJER J.: Eye Tracking. A Comprehensive Guide to Methods and Measures. Oxford University Press, New York, USA 2011.
5. VAN ORDEN K.F., JUNG T.P., MAKEIG S.: Combined eye activity measures accurately estimates changes in sustained visual task performance. Biological Psychology, 52, 3, 2000, 221–240.
6. www.smivision.com; 10.03.2013
7. LIU Y., HSUEH P.-Y., LAI J., SANGIN M., NÜSSLI M.-A., DILLENBOURG P.: Who is the expert? Analyzing gaze data to predict expertise level in collaborative applications. IEEE International Conference on Multimedia and Expo, 2009, 898–901.
8. WIERSMA J.W.F.: Assessing Vessel Traffic Service Operator Situation Awareness. Delft University of Technology, 2010.
9. RATWANI R., TRAFTON J.G.: An Eye Movement Analysis of the Effect of Interruption Modality on Primary Task Resumption. The Journal of the Human Factors and Ergonomics Society, June, 2010, 370–380.