Cognitive Research on Pilot's Eye Attention During Flight Simulator Tests

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Abstract   The paper presents a cognitive research method of pilot's eye attention based on flight simulator tests. The research was carried out using noninvasive SMIRed500 eye tracker on an adapted test stand integrated with Brain Products encephalograph. The paper presents eye tracking methods and their application in various areas. The first part of the paper enables getting acquainted with the software and hardware environment used in the research. The second part is related to practical aspects. The research was carried out on ten subjects qualified in two test groups: NON-PILOT and PILOT. The fundamental part of research is calibration of the eye tracking device and registering of the results of two tasks: the take-off to ceiling of 1200ft AMSL in windless conditions in a configured Cessna 172 aircraft, and landing from the ceiling of 1500ft AMSL in windless conditions on the same aircraft type. The last part of the paper is the comparative analysis of test groups created based on the SensoMotoric Instruments software. The analysis allows for a detailed description of two main measures components of eyeball movements of every test subject. The conclusions may be used for further design and research projects.

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1 Introduction

The development of methods allowing for exploration of the knowledge of human body and the methods of its operation raised a need to analyze and define the form of external stimuli perception by human sight apparatus. The methods originally used would not yield results of quality decent enough, as the range of errors was very big. Then, more advanced methods came into use, they gave good results, and in the course of years they have been upgraded. The present eye tracking methods are at very high level, and they begin to enter the everyday life more and more due to their high accessibility and possibilities of application [4].

2 The modern methods of human eyesight activity analysis

2.1 The basis of eye tracking

Sight is a dominating sense in humans – it delivers the most detailed and fastest data. The proper sight stimulus, which stimulates the eye's retina's receptors is light. With the technological progress, digitalization and the development of eye tracking research it has become possible to precisely analyze the human attention by monitoring of human eyesight activity. The non-invasive methods of cognitive studies may contribute to creation of special optimized glass cockpits enabling the acquisition of a number of important information of flight parameters in a specially created areas in the cockpit. The dynamic development of aviation forces designers to enable the delivery of flight data to the pilot in the most rapid and simple way. Thanks to the eye tracking research it is possible to analyze the distribution of saccades and fixations of pilots with various experience levels in flight training. Eye tracking is a science dedicated to measurements of eyeball movements, usually in response to sight, auditory or cognitive stimuli. There exist a lot of methods enabling the recording of human eyesight activity starting with direct observation, through invasive mechanical methods and finishing with examination of electrical potential difference between two sides of eyeball. There exist a lot of areas of application of eye tracking research, such as medicine, psychology, ergonomics or marketing.

The sight path analysis (fig. 2.1) allows to come to conclusions related to the process of perception. It is possible to conclude which areas have caught observers attention and which have been overlooked, and in which order they have been scanned by the subject.

The history of eye tracking research dates back to second half of XIX century. In 1879 the French oculist, Louis Émile Javal was conducting sight observation using direct observation method, which allowed to conclude, that the eyeball movement is not fluent and that it is composed of saccades and fixations.
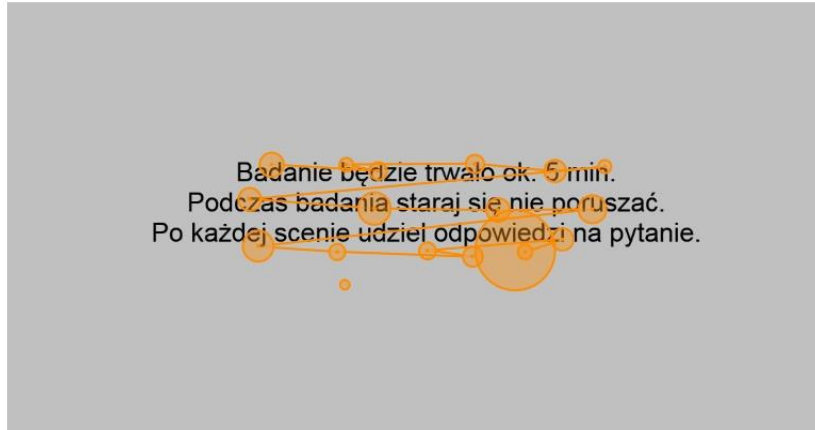
Fig. 1.1. Reading process registered by eye tracker

In the years 1950-1960 the Russian psychologist, Alfred Lukyanovich Yarbus carried out a research on the process of seeing and perception. The have shown, that the movement of eyeballs and the subject's areas of interest are correlated with each other. The results were published in 1967 in the "Eye movements and vision" book. The statement about the possibility of drawing conclusions could be found in the book: "The eyeball movement represents the human thought processes, and for this reason the conclusions of observers on the thoughts of examined subjects related to the examination of given stimulus, may, to some extent, be based on the analysis of eyeball movement. Based on these records it is easy to establish, which elements draw the sight of an observer (and in consequence focus his/her thoughts), in what order, and how frequently."

2.2 Methods and devices for recording of eyeball movement

The modern eye tracking methods include:
- Electro Oculography (EOG) – based on the difference of potential on the front and rear part of eyeball, registering the variation of electric field during eye movement. This method is susceptible to interference and is characterized by limited accuracy.
- Coil systems – based on observation of magnetic coil placed in the eye by surgical implantation methods or use of special lenses – fig, 2,2. In this method the head must be immobilized by bite-on fixture, or additional coil must be used to analyze the head position. This method is susceptible to error, is invasive and potentially dangerous, which is why it is used mainly for the research on animals.
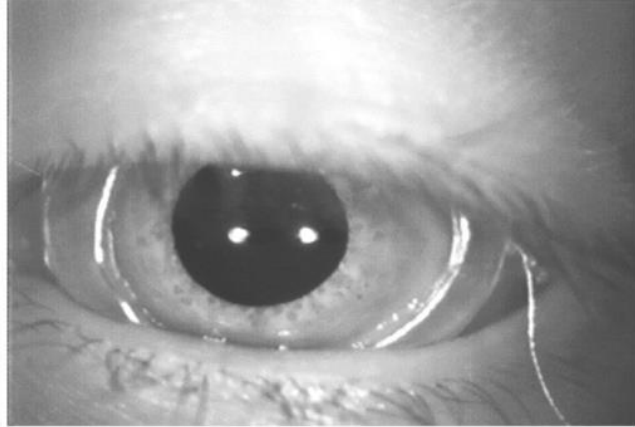
Fig. 2.2. Contact lens with built-in-coil [1]

- Dual Purkinje Systems – this eyeball movement tracking system uses the light reflection on front and back surface of cornea. By the use of complex mathematical algorithm the recording system may establish the position of eyeballs, and further determine the area of interest of the examined subject. The method exhibits high precision, however it requires the subject's head to be immobilized.

- Bright pupil system – uses the beam of infrared rays on the eyeballs and high sensitive camera placed on axis. The light reflected from the cornea is visible as a white spot. The phenomenon similar to the one used in the above mentioned method results in red eyes in the photographs created with use of on axis flash.

Fig. 2.3. Eye tracker SMI Red 500 [2]

- Dark pupil system – the eyeball tracking system using the illumination of eyes and face of examined subject with infrared light and highly sensitive camera. The face and cornea reflect light, whereas the pupil absorbs most

of the rays, and for this reason is easy to identify in the image recorded by the camera as a high contrast dark ellipse. The dark pupil system is versatile and easier to apply, it is characterized by high accuracy, but it requires some sort of head movement compensation. The SMI RED 500 device used in this research is based on the dark pupil system method (fig. 2.3).

The significant characteristics of eyeball movement in the course of eye tracking research are two main components, which are recorded and analyzed [1]

- Fixations – eyeball movements below the limit of speed, which represent the interest of examined person looking at the defined point in the scene. Fixation is composed of minimal drifting movement around the area of interest to keep the look at one point. The fixations are possible to detect by the use of threshold of maximum eyeball movement in the minimal duration of time possible.
- Saccades – the rapid eyeball movements during transition between the areas of interest (fixations). Saccades are detected most frequently by the use of algorithm of minimal threshold values of velocities and accelerations of eyeball

3 Description of software and hardware environment used in the experiment

The Eye Tracker SMI Red 500 used in research has a possibility to work with the software environment enabling calibration, experiment design and recording as well as the deep analysis. The software environment comprises the following components:

- iView X – dedicated software coupled with eye tracker, allowing for execution, calibration and validation. The software algorithm allows to determine the optimal position of the examined subject, which translates to the measurement accuracy. The software enables real-time readout of left and right eye coordinates from Line-Graph chart and measurement of pupil's diameter (fig. 3.1).
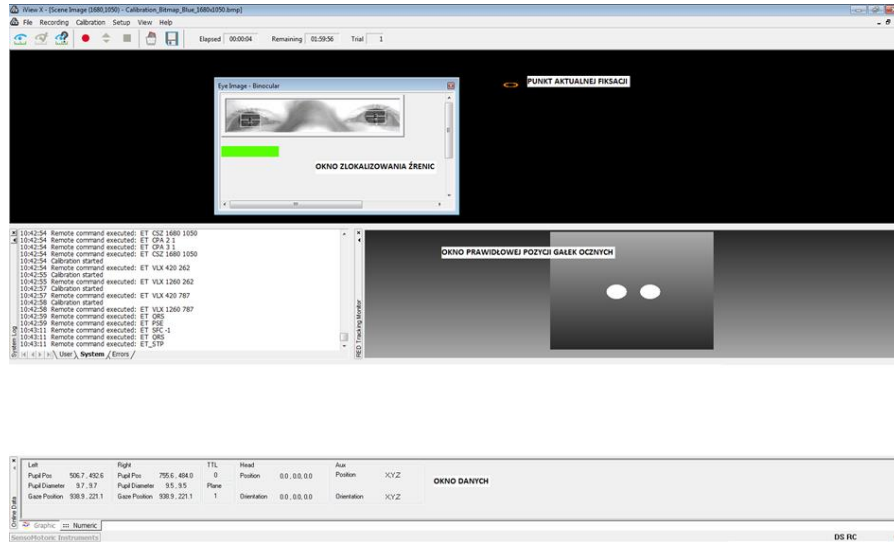
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Fig. 3.1. iView X software during calibration process

- Experiment Centre – the software which offers a broad spectrum of possibilities in terms of experiment design. The software enables to create presentations comprising pictures, text files, PDF files, questionnaires, video clips or the use of screen capture. The user has a possibility to freely edit experiments, add or delete stimuli. The design is intuitive and possible to execute through an array of simple commands selected from the main menu located in the top section of programming window (fig. 3.2).
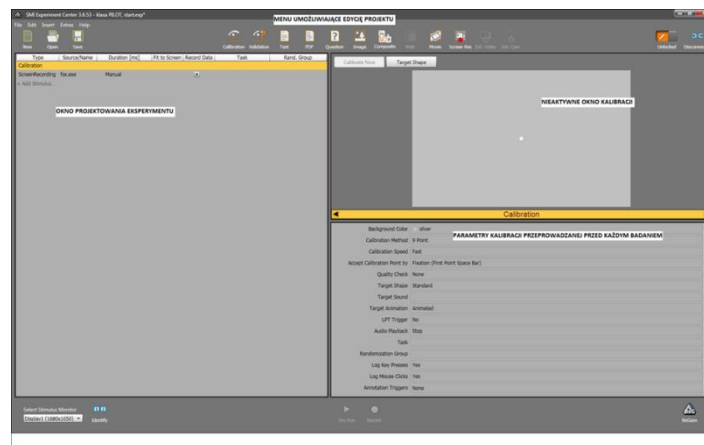

Fig. 3.2. Experiment Centre during creation of experiment

This software was used to define the parameters of calibration required for the conducted experiment. The user has a possibility to edit the following data:
- the color of calibration window
- calibration method (1, 5, 9 point)
- calibration speed
- transition between calibration points
- measurement of accuracy
- calibration point visualization
- calibration point sound
- calibration animation
- LPT release signalizing the start of examination concurrent with EEG device
- sound player
- task assignment
- group presentation randomness
- button use monitoring
- mouse use monitoring
- release of annotation of the defined behavior of an examined subject

To perform the given task, the Screen Recording option, which allows to capture the screen display has been used. The editable parameters are: duration, start application selection and capture frequency. The software also has a possibility to overlay the areas of interest (AOI), which enables identification of areas, which capture the most of examined subject's attention. Overlaid on stimuli it may trigger a transition to the next objects of the project, on condition, that fixation on AOI for a minimum duration of time set by the user occurred. As far as AOI are concerned, they are possible to edit, their size may be changed, or the areas may be multiplied on the examined subject.

- BeGaze 3.6 – the software used for research analysis, carried out through the dedicated multifunctional platform with vast capabilities for observation of the distribution of fixations, saccades, transition paths or heat maps. The software enables export of results in files readable by software such as MS Excel, MATLAB or video files. The results export in this paper was performed by the .avi files. The options, which are available for the user to analyze the carried out research are shown below.

- **Fig. 3.3.** The Scan Path option, the area of depicted circles is proportional to the fixation time

Fig. 3.4. The Heat Map option, the color of an area is depended on the fixation time, starting with blue (short duration) to red (long duration)

Fig. 3.5. The Key performance option displays, among others, information such as: number of fixations, duration of projection, time the first fixation occurred
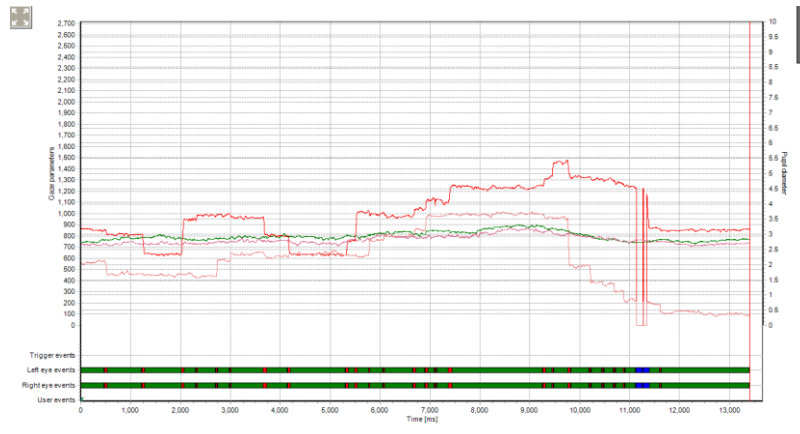

Fig. 3.6. The Focus Map option emphasizes fixation areas on the results area

Fig. 3.7. The Gridded AOI option emphasizes the areas of highest interest taking into account the total time of fixation on the area

Fig. 3.8. The Line Graph shows the sight position, pupil diameter, pupil's acceleration as a function of time

4 Specification of the groups of examined subjects and the characteristics of performed experiment

4.1 Tasks in the experiment

10 subjects took part in the experiment, they were divided into two test groups:

1) NON-PILOT

No. of examined subject	Age	Sex	Flight hours [h]
Examined subject 1	26	Male	0
Examined subject 2	21	Female	0
Examined subject 3	25	Male	0
Examined subject 4	25	Male	0
Examined subject 5	26	Male	0

2) PILOT

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Examined subject 6	24	Male	160
Examined subject 7	24	Male	80
Examined subject 8	32	Male	250
Examined subject 9	28	Male	1200
Examined subject 10	26	Male	835

Table 4.1. Characteristics of examined subjects

The examined subjects were to perform two tasks:
1) Take-off to the ceiling of 1200ft AMSL in windless conditions, in a configured Cessna 172 aircraft (analogue instruments)
2) Landing from the ceiling of 1500ft AMSL in windless conditions in the same type of aircraft.

Every of the performed tasks was preceded by the nine point calibration process, selected results of which are shown below (fig. 4.1, fig. 4.2). In case of calibration process yielding unsatisfactory results, the calibration process was repeated until the reliable readout of eyeballs' movement was achieved.
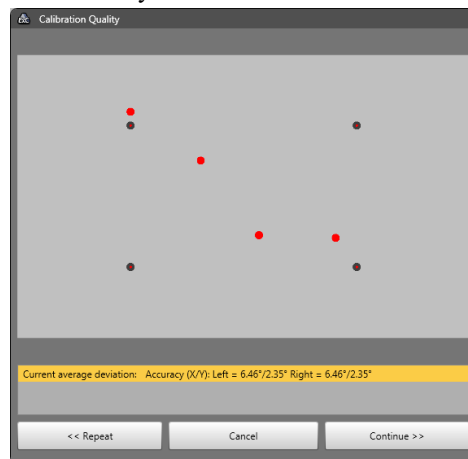
Fig. 4.1. Calibration inaccurate , requiring repetition of the calibration process
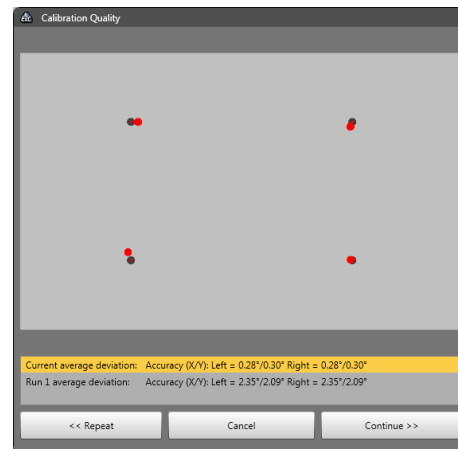
Fig. 4.2. Calibration accurate, no need to repeat the calibration process.

4.2 The course of experiment and the obtained results

The examination of attention of eye of pilots and persons uninvolved in aviation were performed concurrently with the examination of brain activity with Brain-Products encephalograph. The results are shown in the pictures.

The picture (fig. 4.3) shows BeGaze software with Scan Path option examination results of a subject selected from NON-PILOT group. The results show, that during the take-off the examined subject scanned the instruments in the cockpit in a chaotic and random way. The subject payed attention to instruments such as a clock, air inlet into cabin, CDI indicator, fuel meters, EGT indicator, which means that the examined subject focused attention on instruments, which are definitely not the most important for the take-off procedure. It is worth to note the blue lines (saccades) and blue circle areas (fixations) shown in the picture. No transition between to fixation areas means the loss of pupil from the eye tracker's field of view, which means the subject blinked or focused attention outside the screen.

It is worth noting, that in the time frame of 31 seconds the subject performed 232 fixations, 288 saccades and blinked 20 times.

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Fig. 4.2. Distribution of fixations and saccades for a person classified as a NON - PILOT , the option SCAN- PATH

The picture (fig. 4.3) shows BeGaze software with Scan Path option examination results of a subject selected from PILOT group. A subject with some aviation experience during a take-off procedure payed attention to instruments such as: artificial horizon, airspeed indicator, gyrocompass, variometer or altimeter. The eyeball movement of a subject from PILOT group indicate an orderly movement defining unequivocally a scheme of perception of instruments during flight, strictly connected with instruments located in the central part of cockpit of the whole aircraft. The examined subject checked the flap position to take-off before increasing revolutions, in spite of the fact, of he had been informed that the aircraft had been configured for take-off, which may be connected with desirable customs from the real plane. In the time frame of 13 seconds, the examined subject from PILOT group performed 52 fixation, 48 saccades and blinked only 4 times.

Fig. 4.3. Distribution of fixations and saccades for a person classified as a PILOT, the SCAN-PATH option

5 Summary

The eye tracking examination allows for a broad spectrum of analysis of human eye attention. The aim of the paper was the examination of aircraft's cockpit's perception during the critical points of flight. The results obtained by the eye-tracker SMI Red 500 allow to perform a detailed exploration of the accumulated information in order to scientifically interpret it. The experiment carried out on two groups of subjects allowed to capture instruments of high importance for the pilots, and the ones to which less attention is payed. The acquired results have shown the difference of cockpit perception between people with various aviation experience. The eye tracking research are distinguished by high accuracy and offer a broad spectrum of analysis of accumulated results. The method allows for detailed imaging of the form of perception.

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