AN EYE TRACKING SYSTEM: TOWARDS APPLICATIONS IN MARKETING?

[a]MARTIN DOBIAS, [b]ONDREJ HOLUB, [c]VRATISLAV FABIAN

Czech Technical University in Prague, Faculty of Electrical Engineering, Technická 2,166 27 Prague 6, Czech Republic
email: [a]martin.dobias@fel.cvut.cz, [b]holub.ondrej@centrum.cz, [c]vratislav.fabian@fel.cvut.cz

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Abstract: Exploring the emotions that can be induced by properly designed marketing communication messages is a modern and very interesting area of research in marketing. For measurements of the induced emotions various medical devices are used (eg, EEG, MRI, etc.) that can influence the natural behavior of the respondent in the course of the experiment. The following text aims to introduce the possibility of identifying other emotions that may be hidden in pupil size and its changes. An eye camera allows measurement of changes in pupil size depending on the projected visual stimulus. This paper presents the possibility of using eye cameras to identify the emotions that are demonstrated in an experiment carried out with known and unknown logos respectively.

Keywords: emotions, pupillometry, marketing, eye tracking

1 Introduction

1.1 Motivation

A new laboratory for studies of pupillary response was built at the Czech Technical University in Prague. This article presents the experimental setup that is based on an eye-tracking camera. Results obtained during first tests, focused on identifying potential applications in marketing, are included.

In addition to the common measurement of eye movements, the use of an eye-tracking camera allows us to monitor also the size of the pupil and its response to visual stimuli. One potential application for eye tracking is to investigate the effectiveness of marketing communication. With respect to the marketing communication, it is mandatory to monitor and evaluate not only the interests of the individual under test but also his/her emotion and cognition. State of the art methods for determining emotional and cognitive load are based on measurement of physiological variables (e.g. measurement of skin-galvanic potentials, EEG) or sensing activity of various parts of the brain using magnetic resonance[13].

The above-mentioned medical devices limit, to a large extent, the natural behaviour of the respondent in the course of the experiment. It would be very beneficial to replace them with a device that would not affect user comfort. Such a device would likely become a dominant tool for the benchmarking of marketing communication. The eye-tracking camera is a natural candidate for doing so, however, the ability to recognize emotions from the variations in pupil area needs to be proven first.

This article is organized as follows. First, the eye movement laboratory is introduced. Next, an initial experiment is described. Assumptions made, as well as hypotheses to be verified are presented. Finally, the obtained results are given and discussed in detail.

1.2 Description of the experimental setup

The laboratory of eye movements' research is made of a PC station and an eye camera. The laboratory is located in a room without windows so as to ensure constant lighting conditions. The eye camera is composed of hardware components (Headset - Sensor part with accessories) and software components (an application for visual stimulation, including the synchronized recording of measured data). The device measures the pupil area and provides an indication where the person being tested is looking at the moment (x, y coordinates within the monitor frame), including selected statistical parameters and visualization of the measured data. The hardware part consists of a head beam, on which an infrared eye camera and a semipermeable mirror are mounted (Figure 1). This arrangement ensures minimal disturbance of the visual field of the tested person. The camera captures the eye reflection in the near infrared region through the mirror placed before the eye of the tested person. Infrared LEDs illuminate the measured scene with a power that complies with EN 62471 standard[6]. The semipermeable mirror performs its function in the range of 700 to 1000 nm.

Figure 1 - Headset with a digital camera.

The camera is a black and white digital with a 752 x 480 pixel resolution and a data reading frequency up to 87 Hz. The recorded image is directly transmitted via USB interface to a personal computer, in which the accompanying application is installed. Its task is to visually stimulate the tested person and synchronously record the measured data, which are then evaluated. The application is also a means to create actual experiments (pictures, static or dynamic images, videos). It is possible to assign different timing to each stimulus, adapt system calibration according to the requirements of tested tasks, play audio tracks or perform partial graphic processing of measured data (for example: time sequence tracking of image, temperature maps, maps of interest, the zone of interest or graphical comparison of eye movements for different tested persons).

Visual stimuli are projected on a 24-inch monitor with a resolution of 1920x1080 pixels. The accuracy of the eye movements detector, at a 600 mm distance from the monitor, is approx. 0.5°, which corresponds to inaccuracies of about 5 mm. The detection algorithm for finding the pupil center has a reliability of 98% with an accuracy for its area determination of ± 1 mm2. A student with eye tracking in the experiment is shown in Figure 3 and a recorded image of the eye is shown in Figure 2.

Figure 2 - Recorded image of the eye.

Figure 3 - Student with eye tracking during an experiment.

For measuring the light intensity the system is supplemented by a light meter TECPEL DLM-536, which is connected via USB interface directly to a personal computer and records the level of overall lighting (Monitor and Lighting of the laboratory).

1.3 Default assumptions

Eyesight is the sense that allows us to perceive light as well as the colour and shape of objects. It is certainly the most important sense; we perceive up to 80% of all information through vision. The sensory organ of sight is the eye, the function of which is to receive and process respectively, the light stimuli coming from outside into the eye, on the retina. In determining the emotional response to a particular stimulus, in our case, a logotype, we started from the previously presented knowledge about the behaviour of the pupil[8]. We assumed dilatation of pupils for positive emotion and respectively, narrowing for negative emotion. The breadth of the pupil is controlled by smooth muscles contained in the iris, i.e., the circular sphincter innervated by the parasympathetic fibres coming from the oculomotor nerve (III nerve oculomotorius) controlling pupil contraction and dilation innervated by the sympathetic system controlling its expansion. The parasympathetic is part of the autonomic nervous system used to manage internal organs, blood vessels and some other organs, while the sympathetic system is involved in the function of internal organs and blood vessels[12].

It is therefore an involuntary reaction, which is a carrier of objective information, unfortunately, also dependent on other parameters[9]. Among other influences, such as the use of certain drugs, certain neurological disorders, the age of the respondent, the physiological possibilities of the pupil, the respondent's interest – i.e. the observed object, etc., of paramount importance is undoubtedly the light incident into the eyes of the tested person. Higher intensity of the incident light causes a more "defensive" response of the eye, which is a narrowing of the pupil. In the dark, on the contrary, the pupil is maximally dilated. The diameter that the pupil of the human eye can, in point of fact, vary in the range is measured from 1.5 to 9 mm and on the subject it responds with a delay of about 0.2 seconds, with a maximum response between 0.5 and 1 sec[2].

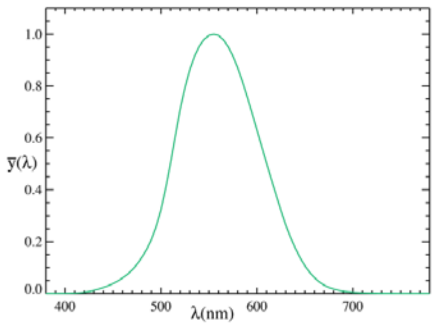

Figure 4 - The photopic vision curve.

From this perspective, it is therefore necessary to create an experiment respecting the above parameters and in particular to the maximum extent possible to suppress the influence of light, so that only the emotional response of the tested person to a given stimulus is actually measured. Measurement of the influence of light on the human eye is the concern of photometry, which compared to radiometry, is based on the knowledge of the sensitivity of the human eye to different wavelengths of the visible spectrum[3]. In Figure 4 the photopic vision curve (in daylight) is shown[5]. This characteristic is used by filters in luxmeters, which measure the intensity of light.

Before identifying the emotional response to a given visual stimulus it is appropriate to project to the tested person a control image, which will have the same value of the luminous flux or light intensity, of the overall brightness, and also similar values of brightness contrast[5]. This follows from the principle of the receiving and interpreting of visual information by the human eye, on which, besides having the effect of sharp foveal vision (about 1-2 degrees), it also causes peripheral vision[11].

2 Design of experiment

2.1 Initial experiment and its objectives

The objective of the experiment was to project to the tested persons selected logotypes and, with the help of the eye camera, to measure changes in their pupil area. The measured data were then compared with information about the familiarity/unfamiliarity with the logotype, which was indicated by the respondent in a questionnaire filled in after the experiment.

The experiment had several objectives:

1. Verify that the technology used is able to detect measurable changes in pupil size when logotypes are displayed on a screen.

2. Evaluate whether the measured pupillary response is related to the respondent's familiarity with the displayed logo.

3. Verify the technical parameters of the experiment, and propose any adjustments needed for further research.

2.1 Design of the experiment

The experiment was made up of seven black and white graphic logos of institutions (KFC, World Wide Fund for Nature, Nike, Playboy, DC shoes, United States Institute of Peace, Yamaha).The logos were chosen so as to maintain a balance between the familiarity and unfamiliarity of students with the logos. In order to minimize the effects of colour on pupillary response, only black and white logos were selected.

In order to distinguish between the influence of image brightness and the influence of the information content (see assumptions above), each logo was preceded by a control image from which any information content was removed. Two operations were considered for the information removal: either smoothing the image by a low-pass filter or replacing the image with a mosaic of squares filled with an appropriate colour. The representative colour was chosen so as to preserve typical hue and saturation in the corresponding image area[1]. Preserving the luminous flux value was approximated by using the average value[10] of the local image area.

Both approaches required the selection of a spatial scale of the modifications. The scale would be a trade-off between sufficient information removal and preserved image granularity. The low-pass filtering usually resulted in an excessive image blur. The mosaic approach allowed for higher local variations in brightness, as can be seen in Figure 5.

Figure 5 –Comparison of low-pass filtering (center) and the mosaic approach (below) applied to a test image (above).

The information removal achieved by the mosaic was further increased by local permutations of the squares. The mosaic squares were grouped into (disjointed) quadruples of neighbours. In each quadruple, one of the following permutations was performed: clockwise rotation, counter-clockwise rotation, or mutual exchange of the opposite squares. The resulting control image is shown in Figure 6.

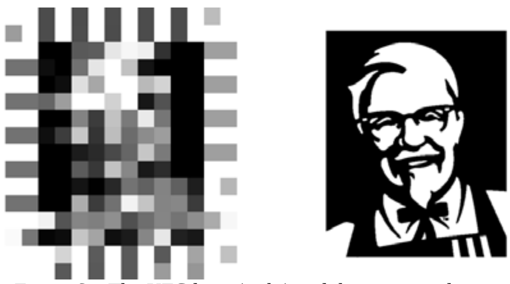

Figure 6 – The KFC logo (right) and the associated control image (left).

The whole experiment was composed of 15 images (see Figure 7) that were displayed on the monitor with the following timing:

1. Black (initial stabilization): 10 seconds,
2. Control image: 3 seconds,
3. Measured stimulus of logotypes: 8 seconds.

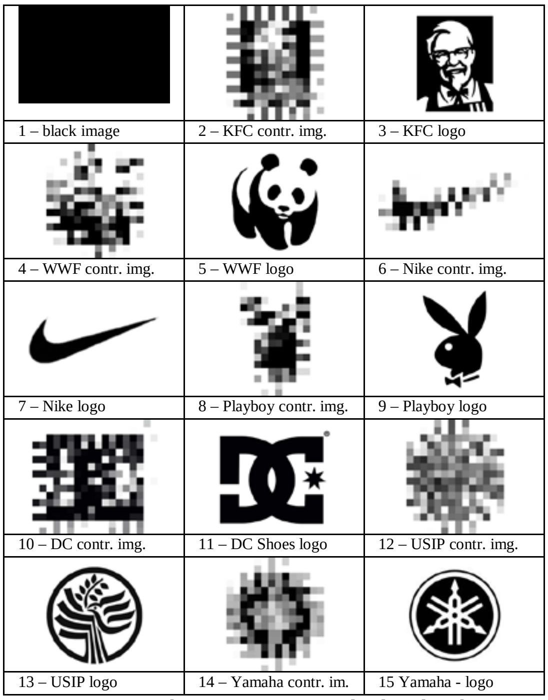

Figure 7 - The images sequence displayed in the experiment.

2.3 Execution of the experiment

The experiment was tested on student volunteers. Only the 23 students who (stated that they) did not use any drugs and did not suffer from any neurological disease were selected for evaluation. Before starting the experiment, it was explained to the students that several logos would be projected on a screen while an eye-tracking camera would record their pupillary response. Then the students were asked to fill in a survey, where they indicated which logos they recognized, which they did not, and which logos they were not sure about.

The measured pupillary responses were quantified using common performance indicators: mean value of pupil area (the initial drop omitted from calculation), difference between maximum and mean pupil area and time to reach maximum area[4]. A typical response along with the performance indicators is shown in Figure 8.

3 Results and discussion

The following observations can be made with respect to the above defined objectives of the experiment. The pupillary response to displayed logos is well captured by the eye tracking camera and image processing software components, as can be seen in Figure 8.

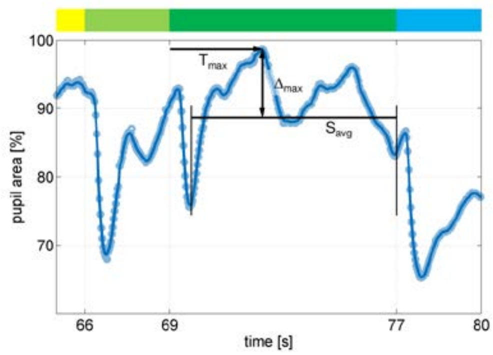

Figure 8 - A typical pupillary response (bottom) to visual stimuli (top, each stimulus represented by a colour). The performance indicators: mean area Savg, maximum dilation Δmax and time to maximum Tmax.

The set of displayed logos was carefully selected to include widely recognized logos, unknown logos and partially known logos, too. The respective statistics are given in Table 1. On the other hand, no correlation between the logotype familiarity and the pupillary response indicators used was found. A sample outcome of the analysis is visualized in Table 1 as well. Performance indicators for the respective groups and images – mean pupil area Savg and time to maximum Tmax. Normalized values represented by a jet colormap (largest in red, smallest in blue). Elements corresponding to empty groups are white.

Logo	Unknown logo	Known logo, but cannot assign it	Known logo
KFC	0%	4%	96%
WWF	43%	52%	5%
Nike	0%	0%	100%
Playboy	0%	0%	100%
DC shoes	13%	35%	52%
USIP	87%	9%	4%
Yamaha	83%	4%	13%

Table 1 – Relative frequencies of known and unknown logos and performance indicators for the respective groups and images - mean pupil area Savg (left) and time to maximum Tmax (right).

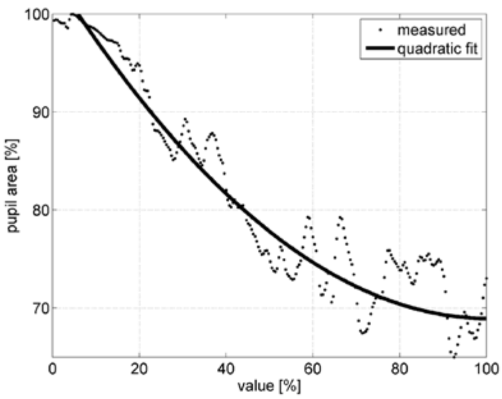

Figure 9 – Measured relationship between hsv value and pupil area. The variations in pupil area are due to the natural oscillations – data measured in one shot.

Timing of the visual stimuli was selected to be long enough to capture the key part of pupillary response. At the same time, the excitation was not overly long (from a marketing perspective).

An issue related to the control images was detected, though. Luminous flux generated by the control images was systematically lower than flux induced by the logotypes. Detailed investigation revealed the issue was caused by nonlinear mapping between luminous flux and the hsv value used to approximate it. A similar effect was measured for the relation between the hsv value and pupil area, as shown in Figure 9.

4 Conclusion

A new laboratory for studies of pupillary response was built at the Czech Technical University in Prague. The first experiments confirmed that, from the technical point of view, the experimental setup can be used for evaluation of pupillary response to stimuli displayed on a computer screen. The measured data is virtually free of noise allowing for robust evaluation of almost arbitrary response indicators. The laboratory environment was well accepted by the volunteers. The selection procedure for displayed logotypes provided a rich enough cognitive load of tested subjects.

The relationship between familiarity with the displayed stimuli and the pupillary response has not been explained yet and would be a natural topic for future research. The results obtained are in contradiction with the former conclusions of[8]. However, validation of these hypotheses was not the main objective of the introductory experiments. In fact, the authors would welcome collaboration with peer researchers active in psychology and medicine on such topics in the near future.

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