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Research on Human Emotion while Playing a Computer Game using Pupil Recognition Technology

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***Abstract* – The article presents the results of an experiment during which the participants were playing an online game (poker), and while playing the game, a special video cam was recording the diameters of the player's eye pupils. Diameter data and calculations were based on these records with the aid of a computer program; then, diagrams of the diameter changes in the players' pupils were created (built) depending on the game situation. The study was conducted in a real life situation, when the players were playing online poker. The results of the study point out the connection between the changes in the psycho-emotional state of the players and the changes in their pupil diameters, where the emotional state is a critical factor affecting the operation of such systems.**

***Keywords* – Pupil dilation, emotion, biometric system.**

1. Introduction

The interdependence between the psycho-emotional state, ideational activity, different emotional stimulus and pupil size variation has been known since ancient times.

In latter days, investigators have been conducting researches using computerized measuring devices.

Research on the interdependence between the pupil diameter and emotional state were carried out by authors in [1]. It was found that when people listen to emotional music, their pupils increased in diameter.

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Authors in [2] described a computer system based on neural networks that is capable of recognizing human emotions (negative, neutral and positive) on the basis of a person's pupil diameter.

Authors in [3] studied the difference in the pupil's reaction to the emotional stimulus between the children of depressed versus nondepressed mothers.

Authors in [4] developed and introduced a learning machine technique that can be used to determine positive and negative emotions by measuring the pupil diameter. They determined that the pupil diameter is larger at a negative sound stimulus than at a positive sound stimulus.

Thus, authors in [5] have been conducting research on the interdependence between the pupil diameter and ideational activity.

Authors in [6] have conducted research on pupil size variation during mental arithmetic tasks performed by people: "We observed a similarly-shaped pupil response to that reported by authors in [7]."

According to [8], pupil size variation seems to behave curvilinearly on the valence scale. It is largest at the negative and positive ends of the continuum and smallest at the centre, which represents a neutral affect.

In research on the dependence of pupil diameter on the emotional state, the selection of the emotional model is important. Discrete, dimensional, appraisal, neurobiological and dynamic models are the most famous ([9], [10], [11], [12], [13]).

In this research, we used a model suggested by authors in [14] that uses several parameters of classification, the Circumplex Model of Affects (CMAs). In this model, while describing the emotions, two independent measurements, valence and arousal are used by Russell [9].

The purpose of the study is to check the hypothesis - whether it is possible to determine the emotional state of the user interacting with a computer program on the basis of measurements of pupil diameter by means of a budget (low-cost) Eye Tracker device. The logic game of poker was used in our study.

This paper is a continuation of the research conducted by one of the authors, where the dependence of the change in the pupil diameter of students upon giving correct or incorrect answers to exam questions has been studied. The results obtained in these studies can be used in the creation of subsystems of multivariate methods for determining emotional states in systems like the Biometric and Intelligent Student Progress Assessment System [15] and the Recommended Biometric Stress Management System [16].

2. Research methods

Using eye tracking technologies for studying the changes in the mental and emotional state of a person interacting with a computer (human computer interaction, HKI) has both advantages and disadvantages. The peculiarities of using eye tracking technologies were considered in more detail by Hayk Khachatryan [16]. In particular, he notes the following advantages of eye tracking technologies important for our study: Natural eye movements recorded, high precision and accuracy, large amounts of data collected.

Hayk Khachatryan [16] notes such disadvantages as well: Difficulty in interpreting results, expensive resources (time, financial, labour). In the studies, we used factors that allowed us to reduce the impact of these disadvantages:

Difficulty in interpreting results:

For a more convenient interpretation of the results, we used the Circumplex Model of Affects suggested by Russell [9] in our studies. In Russell‘s model [9], factorial space is described by independent valence /arousal measurements, arranged as Cartesian coordinate system . According to this model, the human emotional state can be described by the diagram shown in Fig. 1.

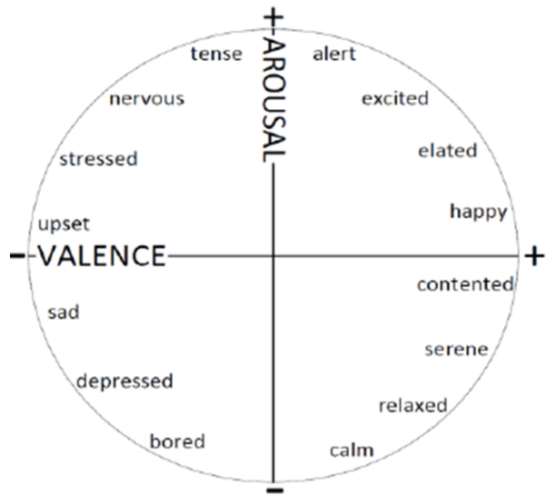


Figure 1. 2D valence/arousal Russell (1980) model [17]

On the ground of this model for our experiments we identified 4 emotions characterizing the specific area of valence and arousal patterns according to the Russell model (1980), Table 1.

Table 1. A table of the correspondence between the emotional state of the participants of the experiment and arousal/valence areas (Aurosal/Valence) according to the Russell model [9].

Aurosal/Valence(Russell's model)	**Emotion**
Moderate arousal positive effect	Happy
High arousal positive effect	Excited
High arousal negative effect	Tension
Moderate arousal negative effect	Upset

Expensive financial resources:

There are a large number of eye tracking devices available for experiments. A comparative analysis of such devices was made by Tristan Hume [18], Edwin S. Dalmaijer [19].

Edwin S. Dalmaijer [19] presents a comparative analysis of the devices: the Eye Tribe and EyeLink 1000. Edwin S. Dalmaijer [19] presents the results obtained in the form of a Table 2.

Table 2. Accuracy (mean difference between target location and observed point of regard in degrees of visual angle) and precision (RMS noise in degrees of visual angle). Data obtained from an EyeLink 1000 and an EyeTribe tracker, using nine calibration points, with a viewing time of two seconds each. (Edwin S. Dalmaijer [19]).

	EyeLink 1000	EyeTribe
accuracy		
horizontal	0.02001	-0.05152
vertical	0.13224	0.18999
precision		
horizontal	0.00005	0.00105
vertical	0.00011	0.00333

Our task was to choose a device that not only has technical characteristics that are suitable for scientific experiments, but was also not expensive.

In our studies, we used a device called the Eye Tribe, which meets these requirements to the fullest extent. Special equipment for head fixation was used.

During the research, we studied the effect of the psycho-emotional state of a person working on a computer on his/her pupil diameter change. For this purpose, we examined the pupil diameter change of online poker players. This choice seemed to be the best for us because the same action programs cause the same human reactions, and these actions are repeated many times, which enabled us to analyse them and systemize the results. During the experiment, the human-computer interaction diagram shown in Figure 2. was used.

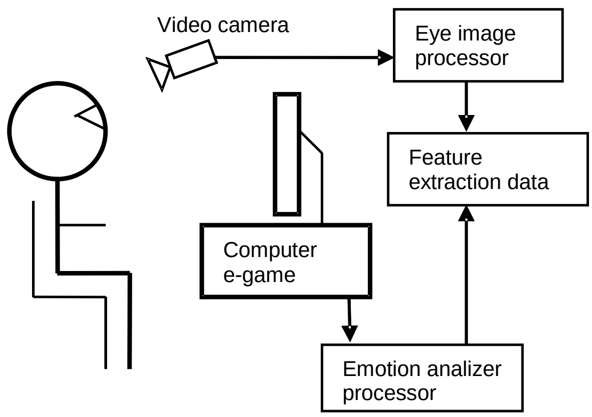


Figure 2. Eye image processor - eye video image processing; Emotion analyser processor - definition of emotions by the timeslot of events; Feature extraction data - determination of the pupil size and corresponding emotion; Computer e-game - computer with a game.

Software for statistical processing: statistical method ANOVA and open source statistical software R-studio.Emotional stimulus: gaming situations arising during a real computer game.

During our experiments we observed the reaction to stimulus, in contrast to the most our studied works a certain game situation, not a visual object was used as a stimulus. This choice of stimulus is explained by the fact that the results of experiment are planned to be used in the real-time emotion recognition systems that often require to determine the emotional reaction to certain situations: knowing-not knowing the answer to the examination question, the occurrence of stress in response to negative information etc.

The experiments were conducted in a room without exterior lighting (the windows were closed with lightproof curtains) with a constant source of light, and the brightness of the source did not change during the experiment. The brightness of the screen changed within the limits of 10 %. During the experiment, no extraneous factors causing an emotional reaction were observed.

Experiment participants:

Our experiments belong to the HKI area of human computer interaction. According to Helen C.Purchase [20], in order to obtain reliable results, 21 people are a sufficient number to be involved in such studies.

As a mediated (indirect) argument for using a small number of participants in the experiments using eye tracking equipment, it is worth mentioning Nelsen's paper [21], in which he says that 5 respondents can show 75 percent of the problems associated with the visual perception of an object. In our case, we can consider the reaction of the player to the image of a game situation as a response to a visual object.

The experiment involved 21 persons: 17 men, 4 women, and the average age was 26.4 years (SD=5.21). All the participants were mentally healthy and had normal or corrected-to-normal vision. All the participants of the experiment were amateur players who periodically (1-2 times per week) played on-line poker games for money. The experiment was conducted under real conditions: in the case of winning, the participant received financial compensation, and in the case of loss, lost his/her money.

They were invited to play poker using online resources. Each player played 3 poker games. The course of the game was displayed on the screen and recorded by a special program to a file.

3. Experiment

With a video camera Eye tracker, an image of the participants' eyes was recorded. Then, with special software, this image was processed and the pupil diameter was calculated at each point in time. The results were logged in a special CSV file.

The course of the game was also displayed on the screen and recorded by the special program to a file.

Upon completion of a game, the participants reviewed the record and commented on the events (set time intervals of the game, game situation: bluff, good cards, etc.) that occurred during the game, according to the proposed template (Table 1.).

Table 3. Game situations and corresponding self-assessment emotional states of the participants of experiment.

Game events	Emotion
Winning	happy
Successful bluff	happy
Good cards	excited
Bluff	tension
Big stake	tension
Loss (beaten)	upset
Losing game	upset
Lost jackpot / loss	upset

On the basis of these comments, special game protocols were created. A fragment of such a protocol is shown in Table 4.

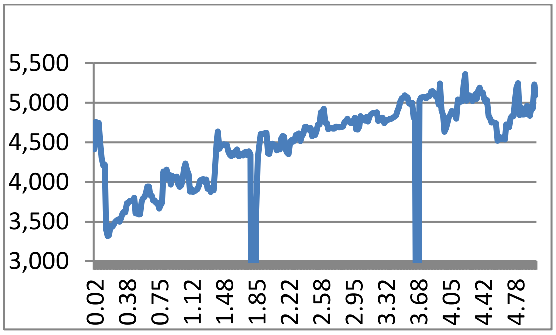
Table 4. Game protocol with time markers of the game's events (Chronological game protocol).

01:36 – good card		06:03 – loss (beaten)
02:11 – lost jackpot		06:28 – good card
02:50 – OP all in		06:45 – big stake
03:21 – lost jackpot		07:09 – big stake
03:26 – lost jackpot		07:11 – winning
04:12 – bluff		07:14 – good card
04:17 – successful bluff		07:41 – all in / good card
04:24 – good card		07:44 – OP fold (winning)
05:25 – good card		08:48 – OP stake
05:46 – big stake		09:17 – lost jackpot (beaten)

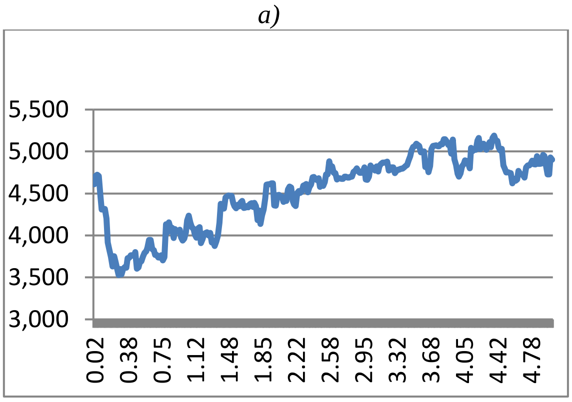
Each participant reviewed the game record and using the particular titles of events set in advance, marked the time intervals of the occurrence of such events. Later these events were grouped according to the certain emotional state: 1 – upset, 2 – tension, 3 – excited, 4 – happy (Table 1.). All data was calculated in an *Excel* spreadsheet.

4. Results

The Smart Eye system and the method of linear interpolation were used in order to filter out low quality signals, as well as data missed (lost) while the recording was in-progress. Fig. 3 demonstrates the difference between the raw data and the data received after processing by linear interpolation.



a)



b)

Figure 3. Is an example of the raw data of the game situation a) and the data obtained after processing with the Smart Eye system and linear interpolation method b) (X-axis: event time in sec, Y-axis: pupil diameter in mm).

About 70% of the data have been recognized as fit for further analysis after processing the data with the Smart Eye system and linear interpolation method.

In total, 1267 game situations obtained from 21 participants of the experiment were analysed. Of these, there were 471 game situations in which the study participants experienced the emotional state of tension, 216 game situations in which the study participants experienced an emotional upset, 304 game situations in which the study participants experienced the emotional state of happiness and 266 game situations in which the study participants experienced the emotional state of excitement.

On the basis of the results of the experiments' median, standard deviation and standard error of the mean of the pupil diameter changes for every participant in all studied, their emotional states were calculated. The results of the research are presented in Table 5.

Table 5. The results of the median, standard deviation and standard error of the mean calculation for every participant on the basis of pupil diameter in 4 emotional states (upset, tension, excited, happy) during the experiment.

	Emotion											
	upset			tension			excited			happy		
	mean	st dev	st err	mean	st dev	st err	mean	st dev	st err	mean	st dev	st err
p1	4.801	0.187	0.011	5.310	0.193	0.011	5.294	0.240	0.014	4.718	0.281	0.017
p2	4.692	0.300	0.018	5.415	0.216	0.012	5.398	0.373	0.022	5.039	0.304	0.017
p3	4.663	0.242	0.014	5.386	0.239	0.014	5.690	0.272	0.016	4.865	0.383	0.022
p4	4.769	0.278	0.016	5.628	0.298	0.017	5.574	0.287	0.016	5.011	0.466	0.027
p5	5.170	0.313	0.018	5.433	0.359	0.021	4.873	0.228	0.013	4.665	0.280	0.016
p6	4.848	0.278	0.016	5.862	0.465	0.027	5.289	0.525	0.030	4.695	0.279	0.016
p7	5.199	0.326	0.019	5.634	0.342	0.020	4.929	0.237	0.014	5.283	0.231	0.013
p8	4.668	0.449	0.026	6.131	0.156	0.009	5.423	0.324	0.019	5.392	0.276	0.016
p9	5.277	0.282	0.017	6.225	0.290	0.017	5.424	0.338	0.020	4.895	0.208	0.012
p10	4.652	0.265	0.016	5.883	0.267	0.016	5.422	0.364	0.021	5.056	0.290	0.017
p11	5.150	0.405	0.024	5.929	0.262	0.015	5.455	0.212	0.012	4.624	0.305	0.018
p12	5.258	0.312	0.030	5.421	0.233	0.014	5.366	0.429	0.025	4.734	0.299	0.018
p13	4.630	0.293	0.019	5.453	0.379	0.022	4.773	0.231	0.023	4.455	0.310	0.014
p14	4.758	0.268	0.015	5.832	0.445	0.026	5.289	0.537	0.015	4.615	0.289	0.017
p15	5.229	0.336	0.020	5.534	0.332	0.019	4.929	0.268	0.022	4.783	0.331	0.014
p16	5.188	0.429	0.027	6.211	0.166	0.011	5.432	0.322	0.033	4.992	0.316	0.015
p17	4.727	0.262	0.018	6.185	0.280	0.018	5.529	0.257	0.032	4.695	0.218	0.013
p18	5.422	0.285	0.015	5.753	0.277	0.015	5.344	0.287	0.019	5.156	0.310	0.019
p19	5.210	0.425	0.025	5.829	0.272	0.016	5.558	0.315	0.021	5.014	0.335	0.017
p20	5.208	0.332	0.029	5.321	0.223	0.013	5.368	0.378	0.018	4.854	0.251	0.019
p21	5.235	0.275	0.023	5.421	0.274	0.018	5.341	0.343	0.021	4.712	0.238	0.014

Using the results of Table 5., after the normalization of the parameters of the pupil diameter median, a schedule of the dependence of the pupil diameter median on the participants' emotional state was made (Figure 4.).

Figure 4. A schedule of the dependence of the participants' pupil diameter median on 4 emotional states (upset, tension, excited, happy).

For every participant in each emotional state, a Kruskal–Wallis test was performed, and in all cases, on the basis of these results, we cannot reject the null hypothesis that all measurements within each emotional group for every participant belong to the same population ($p > 0.05$) Table 6.

Table 6. p-values received during the performance of the Kruskal–Wallis test for each pair of emotional states for all participants (p> 0.05)

	Emotion (p-value)			
	upset	**tension**	**excited**	**happy**
p1	0.533	0.097	0.690	0.734
p2	0.086	0.948	0.087	0.618
p3	0.634	0.089	0.087	0.039
p4	0.131	0.268	0.189	0.865
p5	0.225	0.477	0.929	0.327
p6	0.067	0.252	0.072	0.665
p7	0.695	0.450	0.294	0.066
p8	0.283	0.458	0.318	0.624
p9	0.801	0.574	0.533	0.873
p10	0.692	0.873	0.862	0.189
p11	0.563	0.189	0.634	0.929
p12	0.869	0.318	0.131	0.423
p13	0.478	0.075	0.570	0.724
p14	0.045	0.837	0.075	0.595
p15	0.622	0.080	0.091	0.025
p16	0.111	0.228	0.209	0.742
p17	0.222	0.376	0.871	0.112
p18	0.057	0.362	0.067	0.655
p18	0.595	0.371	0.355	0.053
p20	0.313	0.497	0.298	0.594
p21	0.795	0.614	0.527	0.786

Statistical correlation analysis showed that the samples of pupil diameter measurements during different emotional states significantly differ, see Table 7.

Table 7. Pupil diameter statistical correlation during different emotional states.

	upset	tension	excited	happy
upset	1			
tension	-0.002128	1		
excited	-0.152759	0.326469	1	
happy	0.0730103	0.273238	0.265796	1

5. Conclusion

The aim of the research was to study the dynamics of pupil diameter change using an eye tracker system during the 4 emotional states of 21 volunteers while they were playing a computer game.

Our experiments showed different pupil diameters during the emotional states studied.

As shown in Table 5. and Figure 4., the pupil diameter is larger during the tension and excited states compared with the upset and happy states.

A statistical analysis was performed to examine the statistical significance of the changes in the experiments and the results are presented in Tables 4., 5. and 7.

The observation that the pupil changes occurred at the same time within an experiment value of $p > 0.05$ within each group of emotional states for each participant, indicates that these samples belong to the same distribution (can be considered as originating from the same distribution), see Table 5.

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The studies revealed (Fig. 4) that the pupil diameter depends on the emotional state of the computer poker player. With a sufficiently high degree of precision by observing the change in pupil diameter, we can determine whether these emotional states (excitement, tension) belong to the group of emotional states with a high degree of excitement (arousal positive / negative effect), or to the group of positive and negative valence according to the Russell model [9] (Tab. 2), as in the case with the emotional states “happy-upset”. At the same time, in observing the change of the pupil diameter, it is impossible to ascertain the exact emotional state (excitement or tension) of the player, as we cannot ascertain the exact difference between the emotional states “happy-upset” only based on the measurement of the pupil diameter.

We consider that it is appropriate to use the multimodal method for a more precise definition. In addition, several authors [22], [23], [24], suggest that the multimodal method for determining the emotional state is the most effective one. In this case, the measurement of the change in pupil diameter can be used along with the observation of changes in other biometric and physiological parameters such as speech, heart rate, electroencephalography, skin conduction, facial expressions.

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