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DESIGN OF AN EYE MOVEMENT ANALYSIS METHODOLOGY FOR THE IDENTIFICATION OF VISUAL STRESS DUE TO EMOTIONAL CAUSES

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Abstract: *Good vision requires a visual system that allows a synergistic eye movement to be able to ensure that all categories of properties (visual acuity, color vision, etc.) are at a normal level. Any deviation from the normal functioning state can indicate a visual dysfunction, a pathology or even changes in the functioning of the entire human body. One of the most important aspects in the modern age is the stress that can arise from different causes, single or combined, can affect the general state of physical and/or mental health, can allow the installation of pathologies or can change the occupational comfort. In the first part of the paper, a series of aspects related to the characteristics of the visual function that can change due to visual stress are reviewed, and in the second part, the methods and means used in different fundamental researches on the visual system are analyzed. In the third part of the paper, the conception of a methodology for the analysis of eye movements for the identification of visual stress due to emotional causes is described. In the final part of the work, a series of recordings of this methodology are presented to be able to identify the changes in the visual parameters.*

Key words: *eye movements, visual stress, monitoring vision.*

1. INTRODUCTION

The subjectivity of finite human visual experiences involves complex interactions between the eyeballs, the brain and the environment, providing human finiteness, the sense of sight with all its properties color perception, stereopsis, distance and depth, pattern recognition, motor coordination and many others. The increasing presence of technique and technology in vision processes brings with it the ability to follow, measure and improve the parameters of the visual function in real time, having at the same time the possibility of creating feed-back command and/or reactions control.

The interaction with the environment of the human visual system is one of the most important characteristics of adaptation because it allows the identification, tracking, recording and interpretation of the information coming from it with the purpose of processing, correlation and storage in different forms of action or memorization. In this sense, the oculo-motor system plays a decisive role in allowing orientation, fixing and maintaining the stability of the gaze direction. There are five distinct types of eyeball movement, two gaze stabilization movements: vestibulo-ocular reflex (VOR), opto-kinetic nystagmus movement (OKN); and respective three gaze orientation movements: the saccade movement, the smooth pursuit movement and the synergistic vergence movement. The subjective perception of a stable world with uniform clarity is an important quality that results from the fact that the visual and oculo-motor systems (external musculature of the eyeballs) work perfectly together, allowing the human being to adapt to a complex and dynamic environment.

As mentioned in [1], eye movement information can be interpreted as a sequence of fixation movements and saccades. The fixation movement is represented by the period in which the gaze remains directed towards a certain direction and location. A saccade, on the other hand, is a rapid eye movement between two consecutive fixation actions. In general, a normal visual system performs 3-5 saccade movements per second, but obviously this speed varies according to the perceptual and cognitive demands of the visual stimulation. The saccadic eye movements are short and show a linear relationship (also known as the main sequence) which indicates that the speed of the saccades and the amplitude of the saccade are proportional up to values of 15^0–20^0. This relationship, however, varies with age and with certain dysfunctions or abnormalities of the visual system. Studies of eye movements reveal that saccades are inhibited during engaged visual attention to stationary stimuli and, as a result, a (nearly) constant central fixation is achieved, too [2].

Previous studies [3] also showed that saccade preparation processes can be analyzed by the variation of pupil size during the fixation process and saccade movements. The whole range of fixation and saccade movements represent ways of interacting with the environment. During a fixation, perceptual visual processes unfold and saccades guide the fovea to stimulated regions in the visual field.

The measurement of the pupil diameter during fixation movements and saccades, together with the determination of the duration of the fixation process, the speed and number of saccades, but also the positioning accuracy during them can be indicators of the visual attention process, of the level of visual stress even under the effect of stimulated or simulated emotional states.

Also, the good functioning of the binocular vision is another factor that ensures that the eye movements take place in balance and that the axes of vision of the two eyeballs are directed to the same target point. The correspondence between the images formed on the OS (left eye) and OD (right eye) retinas is a dynamic and complicated process because the two eyeballs are never perfectly still, even when the gaze is focused on an object of interest.

Small fixation movements of the eyes change the degree of alignment between the two eyeballs and continuously change the place where images are formed on the retina. Although these "adjustment" movements of the position take place constantly, only in certain cases, in which the normal limits are exceeded, can the phenomenon of diplopia (double vision) appear which indicates that, normally, the synergistic functioning of the muscular system and the visual system is well regulated.

However, in the presence of pathologies that interfere with the proper functioning of visual or motor mechanisms, such as amblyopia or strabismus, subjects may suffer from diplopia and lack of stereoscopic vision, but also in cases of installation of certain levels of visual stress due to emotional states or of overcoming the state of comfort.

2. METHODS AND MEANS OF MONITORING AND REGISTRATION OF EYE MOVEMENTS

The techniques for monitoring, tracking and recording eye movements involve a series of methods and means based on the characteristics of the visual system. Since this process is dynamic, the evolution of these characteristics is measured over time and the hardware systems transform it into a flow of successive positions of the gaze direction.

2.1 Types of eyeball movements and compatible evaluation techniques

The movements of the eyeballs are the result of continuous, cognitive and complex processes, which involve a series of stages such as: target selection, planning of eye movements, execution of these movements and feed-back control of the entire process. The analysis of eye movements can reveal objective and quantifiable information about the quality, predictability and consistency of these processes in the second plan of action. Among the consistent analyzes that can be performed on eye movements, the analysis of the area of interest (AOI) is a technique for analyzing eye movements, establishing from the first step which are these areas or regions in the visual field that are of interest to the observer.

Unlike the process of obtaining eye movement parameters, which includes their behavior over the entire scene, AOI analysis provides measurable information about eye movement, parameters that are particularly useful for research based on memory, attention, emotional state or reactions to different forms of stimulation.

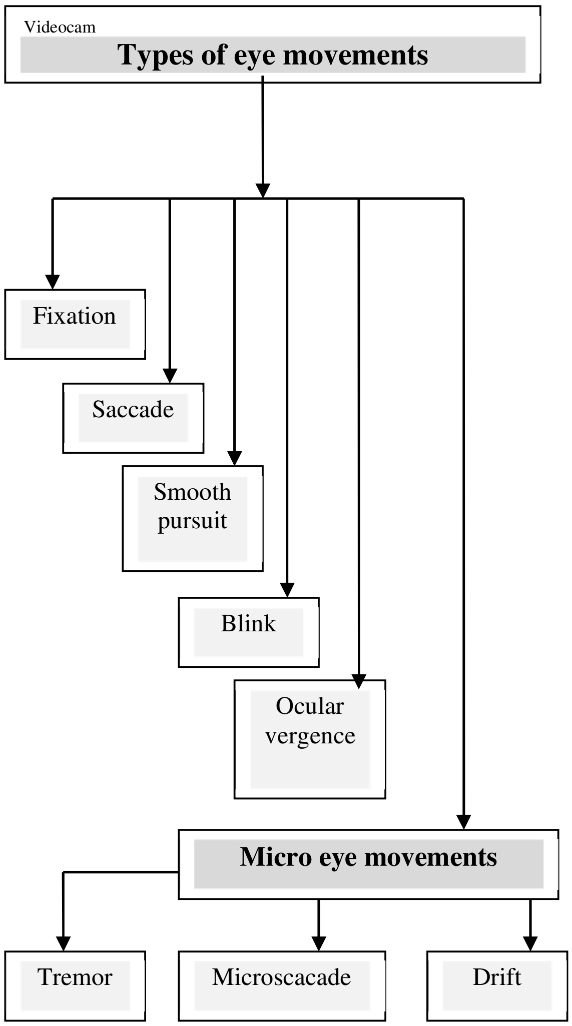

Fig. 1. Categories of eyeball movements. [1]

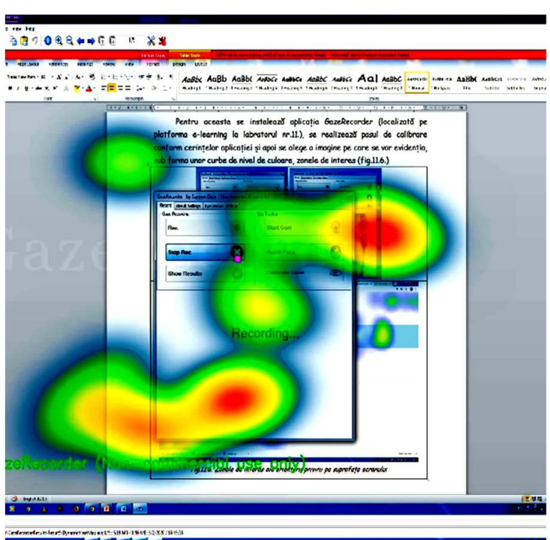

Fig. 2. Topographical map of fixation points of interest.

During the analysis of the area of interest, defining its shape and limits can be difficult due to interactions with other areas in the environment and due to the shape and extent of the visual field, too.

Ideally, each AOI should be defined with the same shape and boundaries as the real object to establish a direct or proportional correspondence. However, due to practical conditions, such as the difficulty of defining arbitrary shaped AOIs given the existence of objects with very different shapes in the environment in eye tracking software, AOIs are most defined using simple geometric shapes (circles, rectangles, ellipses, etc.). Through recent advances in computer vision technology, it was possible to obtain models that automatically and reliably identify objects from the real world, in targeted scenes from the environment (tracking cars in traffic, pedestrians, animals in nature etc.).

This makes it possible to identify AOIs in real-world images almost as easily as with predefined stimuli presented on a computer screen (predefined surface) that the observer can follow in real time [5].

Another important analysis for identifying the way the eyeballs move is the analysis of the spatial distribution map of how the position of the eye's changes in relation to the point of stimulation in the environment. In principle, these distribution maps are based on the generation of a Gaussian model that indicates the probability of locating the fixation points of the eyeballs when stimulation from the environment is recorded.

In general, these graphic representations can be made in real time, the concentration of fixation points in the fixation area being marked either with level curves (topographical) or with a color code proportional to the probability of the density of fixation points (Figure 2).

A third method of eye movement analysis, and perhaps the most used in the practice of eye tracking, is the one by which the directions of the gaze are scanned when stimuli appear in the environment.

Through this method, the movement trajectories of the eyeballs are recorded when they are directed to perform a certain activity (reading, identifying the outline/shape of objects, tracking objects/beings, etc.) that involves movement. These movements are most often accompanied by micro-saccades and short-term fixations that can increase the complexity of the action of recording trajectories, but can be successfully used in other types of analysis (the effects of environmental stimulation, emotional states, and visual stress)

2.2. Movement parameters of the eyeballs in monocular and binocular vision

The movements of the eyeballs (Figure 1) are defined by a series of parameters by which the state of normality or discomfort in which the visual system is located from this point of view can be evaluated.

These movement parameters are:

- *Fixation movement* – the number of fixations related to the time or area of interest (N_f); duration of this action (t_f);
- *Saccade movement* - amplitude (A_s), direction (S_s), speed (V_s), latency (L_s), frequency (F_s), precision (P_s) are parameters that are always related to AOI;
- *The eye tracking movement* - direction (D_{et}), speed, implicitly and acceleration (V_{et}, A_{et}), latency (L_{et}) and the most important parameters, the position error and, respectively, the accuracy of the trajectory realization (E_{et}, P_{et})*;*
- *Blinking movement* – open/closed duration of the pupil (t_{o-c}), frequency of the blinking process (F_b), size of the open pupil (D_{op});
- *Vergence movement* – perceived depth (Δd), distance between gaze positions (Δx), interpupillary distance (D_p) customized for each individual subject.

With all these parameters, in monocular or binocular vision, within normal limits, the level of movement corresponding to the state of visual comfort is achieved.

With the help of the empirical relationship (1) it is possible to estimate the influence of each parameter corresponding to all eye movements, which are considered when evaluating the state of visual comfort.

$$C_{total} = C_F + P_s + E_{et} + C_c + C_V \qquad (1)$$

where C_F = the coefficient of the fixation movement, C_C = coefficient of blink movement, C_V = the vergence movement coefficient, along with the other two parameters specified previously.

But they can be influenced by a series of external stimuli, the influence through which the functional anomalies of the visual system, the state of discomfort or visual stress can be evaluated and compared with the results obtained by other methods.

3. EYE MOVEMENT ANALYSIS METHODOLOGY FOR IDENTIFYING VISUAL STRESS DUE TO EMOTIONAL CAUSES

The methodology for the analysis of eye movements for the identification of visual stress includes several stages with the aim of achieving a unitary way of interpreting eye movements.

To be able to determine the effects of emotional states on the visual system, in the first stage, a simulation (Figure 3) of their effects on the facial shape and especially on the sizes and shapes of the eye areas (eyelids, orbit size, eye orientation, etc.) is carried out. In the second stage, the eye movements of a sample of 5 subjects with visual systems without dysfunctions are recorded, for the same duration of time (20 sec).

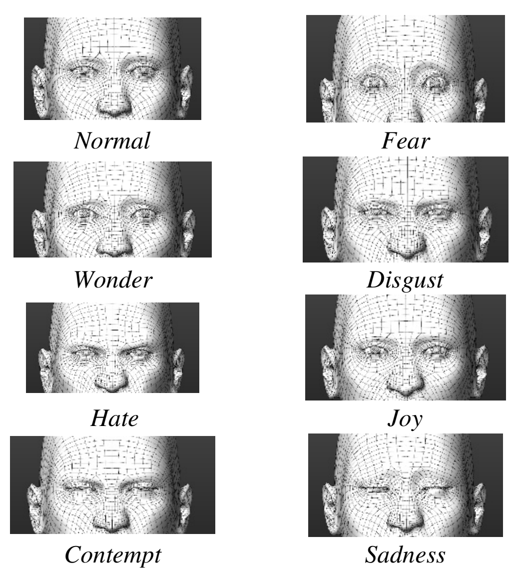

Fig. 3. Different simulation of facial emotional state [6].

The subjects follow a trajectory of bright visual stimulation and receive emotional stimulation at the same time.

In the third stage, the movement trajectories of the eyeballs in the 7 emotional states are mainly quantified to compare them with the trajectory in the normal state, in the case of the sample of the 5 subjects.

From the comparison of these trajectories as well as from the calculation of the visual stress state coefficient (C_{total}) it can be determined if a certain emotional state modifies eye movements and at what level.

4. CONCLUSIONS

As shown in other studies related to the determination of the effects of emotional states on the behavior of the visual system, the method of determining the changes in the forms of movement of the eyes is the most effective option along with the measurement of the pupil sizes. Following the first experiments carried out according to the methodology proposed above, a series of important aspects could be found that can manifest themselves during the tests.

Mainly the environmental conditions (variation of temperatures, noises, vibrations, random light radiation, etc.) can influence the state of concentration, attention and participation of the sample of subjects, sometimes obtaining much too large errors.
However, through the permanent control and adaptation of the way the subjects react and the environment in which the experiment takes place, a level of visual stress can be determined which can then be compared with the values obtained through other analysis methods (biomechanical analyses). For avoiding visual stress, training programs could be a feasible solution [7, 8].

The future study will be developed in the contractual framework of university-industry collaboration [9] and having a positive impact on the companies' quality and performance management [10-12].

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Conceperea unei metodologii de analiza a miscarilor oculare pentru identificarea stresului vizual din cauze emotionale

Rezumat: O vedere bună necesită un sistem vizual care să permită o mișcare oculară sinergică pentru a putea asigura ca toată categoria de proprietăți (acuitate vizuală, vedere cromatică s.a.) să se afle la nivel normal. Orice abatere de la starea de funcționare normală poate indica o disfuncție vizuală, o patologie sau chiar modificări ale funcționării întregului organism uman. Unul dintre aspectele cele mai importante în epoca modernă îl constituie stresul, care se poate instala din diferite cauze, unice sau combinate, poate afecta starea generală de sănătate fizică și/sau psihică, poate permite instalarea de patologii sau poate modifica confortul occupațional. În prima parte a lucrării sunt trecute în revista o serie de aspecte legate de caracteristicile funcției vizuale care se pot modifica datorită stresului vizual, iar în partea a doua sunt analizate metodele și mijloacele utilizate în diferite cercetări fundamentale asupra sistemlui vizual. În partea a treia a lucrării este descrisă conceperea unei metodologii de analiză a mișcărilor oculare pentru identificarea stresului vizual din cauze emoționale. În partea finală a lucrării sunt prezentate o serie de înregistrări ale acestei metodologii pentru a putea identifica modificările parametrilor vizuali.

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