Temporal Aspects of Human-machine Interaction in the Perception of Visual Information

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***Abstract*—The vision system is one of the major sensory systems in the process of human-machine interaction. To improve the quality of interaction it is necessary to evaluate optimal parameters for the speed of perception and volume of visual information. New methods of evaluating the time of visual perception as well as the time of recovery and lability of the vision system are elaborated determining the inertia of the vision system and its ability to perceive visual information. New data on the temporal parameters of visual information processing are obtained through experimental research. The inertia of visual perception is ascertained to depend on the operator's fatigue in the working process.**

Keywords-human-machine interaction; visual perception; inertia

I. INTRODUCTION

The problem of providing human-machine interaction is considered to be relevant and important. The human factor is responsible for more than 70% of all industrial and traffic accidents [1]. The reason for this is the fact that a human's professional activity is becoming more and more complex. As a result, the load on the perceiving, identifying and decision making systems of a person is becoming increasingly heavy.

A mismatch between the information load and the capacities of human perception results in early fatigue of a human operator and errors in his/her work.

Human errors are caused by many factors, poor human-computer interface (HCI), amount of operator's workload, his/her experience, shift-fatigue, etc. being among them [2, 3].

The most badly influenced is vision system providing perception of 80% of all the information actively involved in professional activity.

Temporal parameters of the vision system stipulate the requirements for HCI organization: the speed of information presentation, color, shape and size of objects and their complexity [4, 5].

The fatigue of an operator, the number of errors and labor productivity depend on the parameters of an HCI [6].

The development of HCIs adaptively configured to user, depending on the degree of his/her fatigue and difficulty of the tasks performed is of current interest.

All this requires knowledge on the mechanisms of visual information processing, the temporal dynamics of visual perception indicators.

Thus, the study of information interaction between a human operator and a technical system, aiming at determining the optimal modes of their operation, is of paramount importance.

The objective of the current work is to obtain new data on the processes of perceiving and processing visual information.

In this paper, a new method of recovery time determining, method of visual perception time evaluation and method of the vision system lability evaluation are developed. The results of modeling and new data on the temporal parameters of visual information processing are obtained.

II. APPROACHES TO RELIABILITY CONTROL

According to the analysis carried out, enhancing reliability of man-machine systems requires taking two basic approaches:

- Adapting the structure of information flow and interface parameters to the needs of an individual human operator [7].
- Adapting the user to a computerized system [8].

There is a progress in the achievement of certain quality indicators in both approaches.

Adaptive interfaces are aimed at changing and optimizing themselves automatically, depending on the workload of the operator and dynamically changing characteristics of the medium [9].

It is known that using intellectual adaptive interfaces allows considerably reducing the time expenses of the operator and the volume of his/her work, helping to make correct decisions [10].

Adaptation of the interface parameters is carried out through the automatic correction of the user errors [11], changes in the level of complexity of the interface [12], adaptation to the intensity of information exchange between the user and the system, customization of the technical system to the aims and intentions of the user [13-15], etc.

Simplification of information blocks is one of perspective methods of the organization of modern user interfaces [16].

The methods and means of adapting a user to the system are mainly based on the user study and training. To organize

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adaptation of the user to the system it is necessary to take into account his/her physiological characteristics, behavior and physical state, for which testing (diagnosis) of the user to form his/her psycho-dynamic portrait is implemented [17].

It should be noted that both methods are based on the data about the processes of information perception and processing by a human.

There is a large number of methods for studying the processes of information perception such as the critical flicker frequency (CFF) [18], the time of visual identification [19, 20], the visual sensation [21] and etc. obtained by numerous experimental data on the temporal aspects of processing.

At the same time, the data obtained by different researchers are not systematic by nature and sometimes contradictory.

This brings about the development of new highly accurate and reliable methods and systematization of methodological base.

III. RESEARCH METHODS

The information used by the operator strongly differs by complexity, the form of representation and information content.

To determine potential ability of perception it is necessary to use the information being the simplest for perception. This provides the maximum speed of information processing.

Such condition is satisfied by light pulses of rectangular shape of the "yes-no" type.

Besides, this method of evaluation of the critical flicker frequency is well known in the studying of the processes of visual perception [18].

Critical flicker frequency is the frequency of light flashings per second at which the subjective flicker fusion takes place.

The disadvantage of this method is its low accuracy, low reliability of measurement results.

The research results of the CFF are achieved at successive masking caused by a rhythmic sequence of light pulses, which hinders visual information processing.

A number of new research methods into the visual perception time aspects based on the CFF method has been worked out.

A. The method of recovery time determining

Recovery time (RT) of the visual system is the time during which the vision system is not able to accept a new flow of information. It is the time interval between the first and the second light pulses during which the impulses are perceived separately.

To determine the recovery time a human is supposed to be exposed to a sequence of pairs of light pulses of fixed duration τ_{imp} (Fig. 1).

The pause between light pulses t_{PI} is reduced to critical value t_{cr} at which the fusion of light pulses in a pair is observed (Fig. 2).

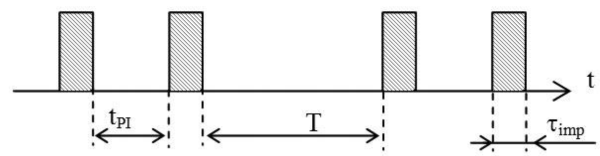

Figure 1. The time diagram of sequence of pair light impulses

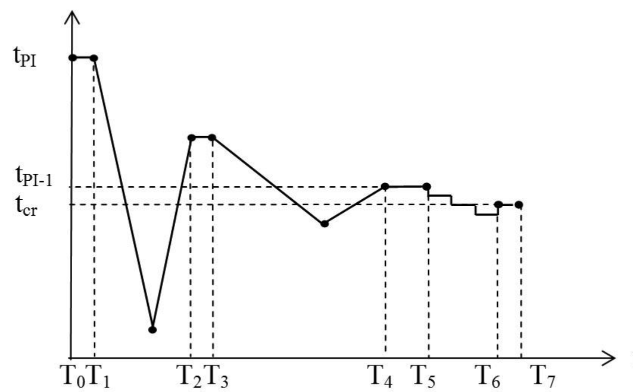

Figure 2. Changing the length of the pause diagram.

The pause at this point is taken equal to the recovery time of the vision system.

To shorten the measurement time at intervals $T_0 - T_4$ the change of the pause length occurs continuously at different speeds. To enhance the accuracy at the final stage (interval $T_5 - T_7$) the change of the pause length occurs discretely with a step of 0.1 ms.

It is known that at light pulse duration of 40-50 ms the processes of neurons receptive fields restructuring in the vision system terminate. Therefore, the duration of light pulses τ_{imp} is chosen to be 50 ms not to disrupt the process of visual perception.

It is also known that a consistent visual masking is observed at time intervals less than 800 ms. Therefore, the time interval between pairs of light pulses T is equal to 1 sec.

As the operator works with visual information of various colors, it is meaningful to carry out research of vision system restoration time on several colors.

The measurement technique will be modified as follows (Fig. 3).

After determining the recovery time on one of the colors $t_{cr\ 1}$ (T_7), the pause between the paired light pulses is increased by a random value. Then the color of the light pulses is changed, and the process of evaluating the recovery time is repeated. The duration of the pause varies discretely with a step of 0.1 ms.

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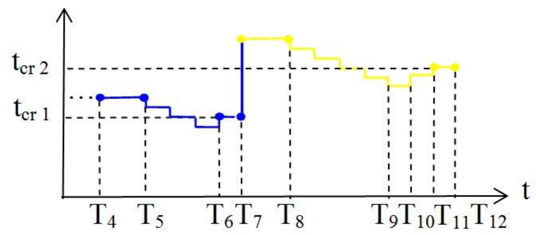

Figure 3. Changing the length of the pause with different colors diagram.

When using light pulses of different colors the process of measuring on the interval $T_7 - T_{12}$ is repeated as many times as necessary.

B. The method of visual perception time evaluation

Time of visual perception (TVP) is an integral parameter of visual perception inertia. TVP is the period from the start of a short exposure test stimulus to the inclusion of a masking stimulus, when the latter cannot interfere with the test stimulus comprehension.

The time for visual information processing is known to depend on the exposure time of test stimulus.

The advantage of the method for determining TVP consists in the fact that it takes into account the duration of the light stimulus exposure.

To define TVP it is offered to use the method of visual system restoration time evaluation. Similarly, a human is exposed to a sequence of paired light pulses, and the duration of a pause at which light pulses in a pair fuse is evaluated.

TVP is accepted equal to the sum of the pulse τ_{imp} and the pause t_{cr} duration at the time of light pulses fusion.

The method of determining TVP technique is similar to the recovery time evaluation method described above.

C. The method of the vision system lability evaluation

The lability of the vision system is an integral value of the lability of the central nervous system and changes in functional status of a human as a whole.

Lability characterizes the ability of the nervous system to react to excitation in exact conformity with the rhythm of stimulation.

The determination of lability is also suggested to be carried out, basing on the method of visual perception time evaluation.

To define the lability of a vision system the examinee is exposed to paired light pulses of fixed duration. In each series of experiments the duration of light pulses is different and equals 110, 90, 70, 50, 30, 10, 5 and 1 ms.

At each duration of light pulses a pause between light pulses in a pair at which impulses fuse is evaluated.

The method of a pause evaluation is shown in Fig. 4.

For each duration of light pulses TVP is calculated and a graph of TVP is built based on the duration of the light pulse, evaluating the minimum functions.

The lability of a human vision system is taken equal to the value of the repetition frequency of light pulses at the minimum point of Hz function:

$$F=1/(\tau_{imp}+t_{cr})$$

τ_{imp} – duration of the light pulse in seconds; t_{cr} – pause length between the light pulses during which the light pulses fuse.

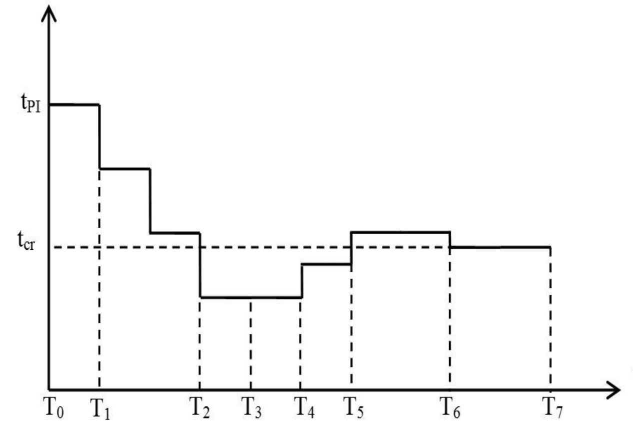

Figure 4. Changing the length of the pause diagram.

IV. MODEL OF THE VISION SYSTEM

As the analysis of literature shows, there is a great number of vision system and its subsystems models.

Our task was to develop a model that can be used for the methods elaborated and can explain the differences in temporal dynamics at the perception of light stimuli of different colors. The structural model based on the data about the vision system structure is presented in Fig. 5.

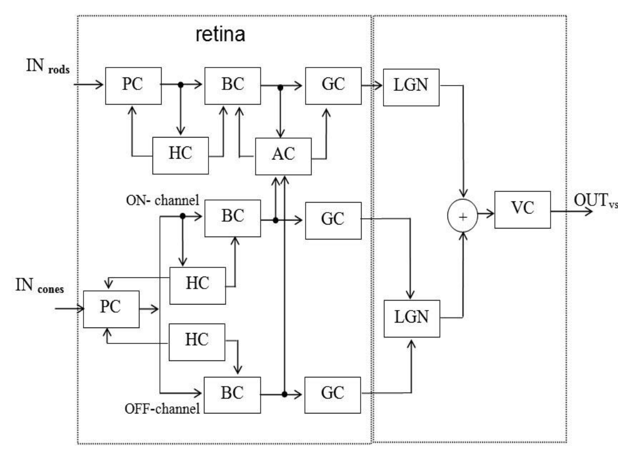

Figure 5. Scheme of the visual system, PC - photoreceptor cell, BC - bipolar cells, HC - horizontal cells, AC - amacrine cells, GC - ganglion cells, LGN - lateral geniculate nucleus, VC - visual cortex, VS – visual system.

This model considers division on rods and cones paths of perception and on-, off-channels.

This agrees with the data obtained by T. Gollisch & M. Meister, 2008 [22], that for adequate simulation of the vision system it is necessary to consider the parallel ON- OFF channels.

For mathematical modeling the well-known transfer functions of neurons and retinal neurons were used.

The results of modeling the perception of paired light pulses of 10 ms are shown in Fig. 6.

The dependence of visual perception on the pulse duration is shown in Fig. 7.

Here the point on the graph with duration of 10 ms corresponds to the lability of the visual system.

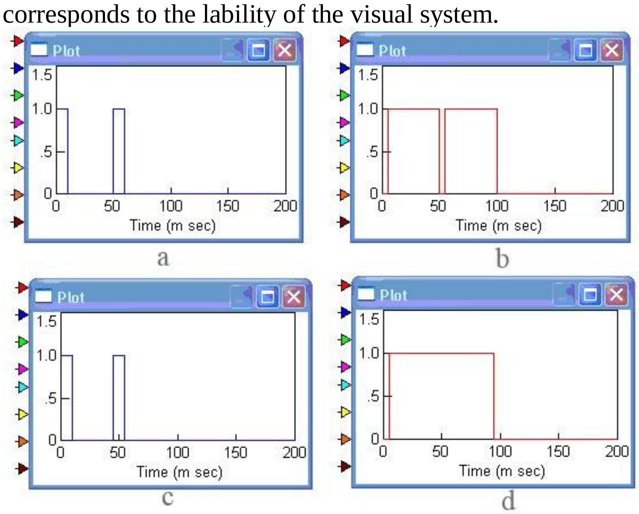

Figure 6. Results of modeling the perception of paired light pulses of 10 ms; a) timing diagram of the two input pulses of 10 ms, separated by a pause of 40 ms; b) timing diagram of the output pulses model presented in Fig. 6 a; c) timing diagram of the two input pulses of 10 ms, separated by a pause of 35 ms; d) timing diagram of the output model to pulses presented in Fig. 6 c.

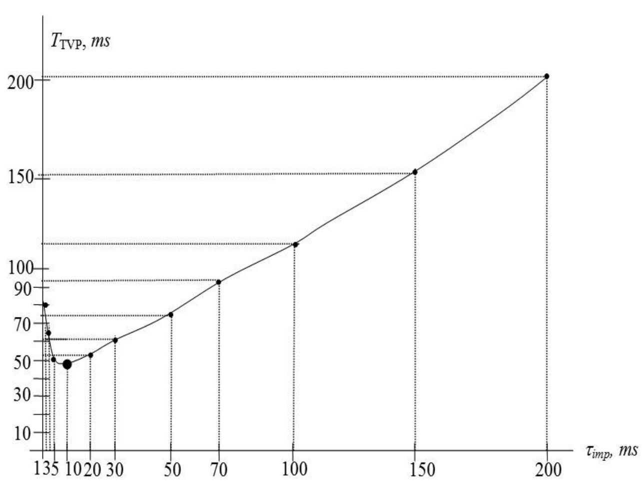

Figure 7. Dependence of visual perception on the pulse duration diagram.

V. EXPERIMENTAL RESULTS

Experimental research was conducted in a group of 30 operators. The time of vision system restoration, the time of visual perception and lability were evaluated, basing on the methods mentioned above. The source of light pulses was LED of yellow color.

The experimental results are presented in the table below.

TABLE I.

№	Estimates of the temporal parameters		
	Value of time parameter	***Individual values***	***Median for the group***
1	Recovery time	12,7 … 37,9 ms	22,9 мс
2	Time of visual perception	62,7 … 87,9 ms.	72,9 мс
3	Lability of the visual system	11,1 … 24,6 Hz.	19,4 Гц

The data concerning the time of restoration and the time of visual perception as a whole correlate with the data from other researchers. The accuracy of the methods developed above is 18-25% higher in comparison with the methods known.

The data on lability of visual system coincide with the data received by means of electrophysiological methods and do not coincide with the data received by means of the CFF method.

In the method described above we eliminate masking effect obtained during the perception of paired light pulses. This explains the difference in the data obtained from those obtained by the CFF method.

The accuracy of the method described above is 17-38 % higher than of the CFF method.

The main advantage of the methods developed is their simplicity; they provide an opportunity to evaluate visual exhaustion.

VI. CONCLUSION

Thus, we have developed new methods of studying temporal aspects of human-computer interaction in the perception of visual information.

All the methods developed are protected by Russian patents for inventions.

We developed the model of visual perception; established the dependence of time of visual perception on the duration of impulses.

Separation on rod and cone paths allows simulating the change of light and the spectrum of light pulses. This is determined by the fact that the rods are most sensitive to blue color and the cones are most sensitive to yellow one. In this RGB triplet and theme map of the ganglion cell were ignored.

We obtained new data about the time of restoration, the time of visual perception and lability of a vision system.

The data are consistent with the simulation data, which confirms the adequacy of the model.

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The results obtained can be used to develop human-focused communication devices, displays as well. They will allow to choose characteristics of video terminal devices so that the maximum consistency of a video display device and a vision system be achieved.

It will also be possible to raise the exchange intensity in the "display-person" system, to increase the reliability of data communication, and to reduce the negative influence of a video terminal on a vision system.

The results of the work can be used to develop human centered HCIs, as well as adaptive HCIs taking into account the peculiarities of visual perception and their change at shift-fatigue of an operator.

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