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MODEL AND METHOD FOR EVALUATION AND FORECAST OF THE CHANGES OF VISUAL SYSTEM FUNCTIONAL STATE IN CONSEQUENCE OF VISUAL WORK

Introduction. *During mental work, 90% of information is perceived by the human visual system (VS), so the effectiveness of the activities depends on the quality of the VS functioning and the presenting of visual information, especially non-traditional forms (TV, personal computer monitor, miniature displays on mobile phones, e-books). Prolonged information overload can lead to the states such as chronic stress, chronic fatigue syndrome, neurosis, occupational burnout and astheno-*

pia, which worsen the operator` functional state, affect the quality of work tasks performance, last a long time and require special correction and treatment.

The purpose *of the paper is to develop a method for evaluating and predicting the operators` functional state based on a model for predicting changes of the VS state under the visual work, as well as to implement this method in clinical decision support system for analyze the SV states changes because of visual work.*

Results. *Two clusters have been identified according to the mechanisms of changes in the VS state due to visual work. A model for predicting these changes is developed based on a set of indicators of the SV functional state using the fuzzy clustering algorithm (c-means) and the fuzzy derivation system Sugeno. According to results of previous research and this forecast model, a method for assessing and forecasting the functional state of an operator and his visual system has been developed. The proposed method is implemented in clinical decision support system for analysis and prediction of changes of the operator's VS state due to visual work.*

Conclusions. *Developed method and automated system allow to predict changes of VS state in the case of a given visual load, to compare the current functional state with the previous one, to obtain information about the effectiveness of the recommended preventive measures. Approbation of the developed system determined that the use of this method of operators` functional state assessment and prediction, as well as recommendations for individual correction of the existing state led to improving of visual function in 67 % of patients, and reducing of overall complaints in 50 %, visual complaints in 53 %, eye complaints — in 40 % of patients.*

Keywords: *functional state of visual system, visual load, model for forecasting of VS state, asthenopia, fuzzy clustering, clinical decision support system.*

INTRODUCTION

Assessment and prediction of the person` functional state (FS) in various types of mental and physical work, despite the considerable number of studies performed in this direction, are pressing questions. A large number of modern professions require the perception and processing of large amounts of information, the intensity of which often exceeds the individual physiological capabilities, which causes significant nervous and emotional stress and negatively affects health.

In mental work, 90 % of information is perceived by the visual system (VS), so the effectiveness of the activities depends significantly on the quality of the VS functioning and the presenting visual information. A large number of non-traditional media (television, personal computer (PC) monitor, miniature displays on mobile phones, eBooks etc.), the quality and methods of image formation of which are much different from the usual paper media, are used.

Prolonged information overloads can lead to the formation of states such as chronic stress, chronic fatigue syndrome, neurosis, occupational burnout and others. Astenopic states worsen the operator` FS, affect the quality of work tasks performance, last a long time and require special correction and treatment [1–6].

All this makes topical research of the visual information impact on the VS state, the development of methods for assessing and predicting its changes under the influence of visual work.

PROBLEM STATEMENT

The problem of preventive diagnostics is at the forefront, which allows to monitor in the early stages deviations of a health state and to carry out its correction. The use of mathematical models as a tool to evaluate and predict the effects of factors that affect VS or promote fatigue is expanding.

Nowadays, fuzzy methods of processing the results of physiological systems studies, in particular the functional state of the visual system, are increasingly used.

The term "soft calculations" was introduced by Lotfi Zadi [7] and means a set of inaccurate, approximate methods for solving problems that often do not have real-time solutions. Such calculations in medicine have great prospects, since the very process of diagnosis is the attribution of the patient to the appropriate class of diseases according to his symptom complex. The fuzzy methods make it possible to solve successfully the classification problems, since it is difficult to draw a clear line between health, pre-illness and disease [8, 9].

To predict the risk of disease or complication, as well as to classify patients` states, doctors usually evaluate risk factors verbally or in linguistic variables [10]. That is, the criteria are fuzzy values and may be characterized by the presence of boundary conditions when it is not possible to determine precisely whether the criterion under study is a risk factor or not. Therefore, it is advisable to use fuzzy decision-making logic as a mathematical basis to develop information technologies for decision support [11–13].

In ophthalmology, fuzzy methods are used to solve medical image recognition tasks [14] for the evaluation of elements of the pathomorphological picture of the fundus [4] for the classification of hemodynamics types in the ocular arteries in the case of diabetes mellitus according to the results of Doppler studies [25, 26] and for the creation of classification systems for different states of the VS elements.

Fuzzy clustering (the c-means algorithm) was used to recognize the MRI images of patients' eyes to identify pathological tissues, form zones of interest, and analyze the results of the eye vessels fluorescent angiography [15].

To form visual pathology risk groups in children and adolescents under the influence of visual labor, a prediction model based on fuzzy clustering was developed, and the rules for assigning subjects to certain clusters that corresponded to different VS states were obtained [16]. The impact of the VS states of the subject under test of a particular cluster, the characteristics of which were identified in the research, allowed us to assess the risk of visual pathology development. A two-stage fuzzy clustering algorithm was used to identify the causes of horizontal strabismus using the parameters of the interference pattern of the eyes [17].

Assessment of the features of the VS functioning in the mental work, it is advisable to consider as a basis for the development of methods for detecting abnormalities in the functioning of both the visual system and the whole organism. The timeliness of such studies is confirmed by the significant increase in the number of asthenopic complaints and clinical pathology of the visual system, not only in children but also in the adult able-bodied population of Ukraine [18].

The development of new information technologies for the functional state assessment of the person under the visual work conditions, using classification fuzzy models will allow revealing the peculiarities of VS adaptation mechanisms to the visual load. Taking these features into account will make it possible to predict changes in the VS functional state and to develop measures for the visual disorders prevention.

The purpose of the paper is to develop a method for evaluating and predicting the operators` functional state based on a model for predicting changes in the VS state under the visual work conditions, as well as to implement this method in clinical decision support system for analyze the SV states changes because of visual work.

MODEL FOR PREDICTION OF VISUAL SYSTEM STATE CHANGES AFTER VISUAL WORK

Features of changes in the operators` VS state due to intense visual work. In our previous work we investigated the dynamics of the visual system state of operators working with a computer monitor [19]. These studies were attended by professional PC operators. Ophthalmic examination of the operators included the determination of visual acuity (OC) of the right and left eyes, distance and near accommodation reserve (AR) at a distance and close in, the position of the nearest clear vision points (Nt) of both eyes and the nearest convergence point (NCP), etc.

For all operators before and after visual work have been determined the functional indicators of the VS (Visual acuity (Va) AR NCP). We also evaluated the expressiveness of asthenopic complaints. Taking into account these complaints expressiveness it is essential to assessing the person` VS state in a real work environment. For this purpose, a questionnaire was developed, covering questions on three scales of complaints: general, visual and ocular accordingly.

According to the results of the initial evaluation of the visual system indicators revealed a significant variation of their values, which may indicate the research group heterogeneity. To determine homogeneous groups, the clustering of the obtained data was performed by the k-means algorithm and two clusters were identified. The analysis of the values in the clusters before visual work allowed us to establish that the first cluster includes operators with high functional indicators of the VS that meet the age norms, and the second — operators with low functional indicators for visual perception in the distance and in near manifested by low Ra, increasing of distance of NT and NTK from the eye and do not meet the norms of visual function for this age group.

An analysis of the data obtained after work (test 2) showed that the level of visual information perception in clusters is significantly different. It should be noted that the more pronounced changes in indicators, which provide close perceptions, took place in the first cluster, the persons of which were characterized by the best state of the VS before work (test 1). Also, in this cluster a significantly ($P < 0.05$) greater increase of the visual asthenopia expressiveness was obtained than the operators of the second cluster, who had initially worse VS status. This fact should be used to construct a model for the individual prediction of the visual asthenopia expressiveness resulting after visual work.

To build a **model for predicting VS state changes** because of visual work, we had used a set of indicators, which were revealed different mechanisms of visual workload influence on the VS state in different clusters. In order to ensure an automatic mode of such a procedure with increasing the research volume, the prediction model was developed using the fuzzy clustering algorithm (c-means) and based on the fuzzy Sugeno inference system performed on a fuzzy base [20]:

$$(x_1 = \widetilde{a}_{1j}\ \Theta_j\ x_2 = \widetilde{a}_{2j}\ \Theta_j\ \ldots x_n = \widetilde{a}_{nj}) \Rightarrow y_j = b_{j0} + \sum_{i=\overline{1,n}} b_{ji} x_i ,$$

where $\widetilde{a}_{nj}$ is a fuzzy term by which the input variable x_n is evaluated in the j-th rule; n is the number of rules in the database; Θ_j — logical operation that unites the j-th rule fragments (logical operation "AND", "OR"); $\Rightarrow$ — fuzzy implication; b_{ji} are the coefficients of a linear function (output) given by some real numbers.

Figure 1 shows two ways to tuning procedure of synthesis and adjustment of the prediction model the PC operators` VS state. The training sample (for model synthesis) consisted of functional VS indicators (Ra and Nt), and the operators` age. The data are presented as a matrix, and their subtractive clustering, known as the mountain clustering algorithm, developed by R. Jager and D. Filev was done [21]. The advantage of this algorithm is that there is no need to specify the number of expected clusters and it is determined during the algorithm execution. Each received cluster corresponds to one fuzzy rule, and the coordinates of their centers are the coordinates of the membership functions maximum (parameter b). A set of logical rules and membership functions form a fuzzy knowledge base and its formal record is a predicting model of operators` VS state.

After synthesis of the knowledge base, the procedure of tuning it up is performed. To do this, it is loaded into the Sugeno fuzzy output machine to it's input the matrix of VS functioning indicators (the primary data used during clustering) is served, and then the output is considered as the SV state forecast. Next, the accuracy of this model is estimated using the actual VS state data obtained by the expert. To minimize the forecast error, the compression-stretching parameters of the membership functions (parameter c) are adjusted (way 1, marked in Fig. 1). This procedure is repeated cyclically until the value of the discrepancy between the predicted (according to the model's findings) and the actual (according to experts) VS states becomes minimal.

This setting is likely to give you a model that matches only the training data. To exclude this effect, an additional test was performed using the following approach: one row corresponding to the data set of one particular test participant was extracted from the training sample and a model was synthesized again to calculate the VS state projection for the entire sample [22]. This procedure is reiterated for each set of particular test participant` indicators in the sample.

Because the discrete values of the cluster conditional number — 1 or 2 are obtained at the output, the error during validation is defined as an erroneous assignment by the model of any of the test participants into a cluster other than the original one. If no errors are identified, the verification is considered complete and it is concluded that the model describes the general processes of VS state changing, and not just a separate data set with the help of which model was developed. To reduce the amount of knowledge base of the fuzzy system, which in this case is determined by the number of clusters, use an additional tuning procedure (way 2, marked in Fig. 1). To do this, cyclically change the clustering procedure parameters (acceptance and rejection coefficients), re-cluster the matrix of VS functioning indicators, synthesize the adjusted model, check its accuracy and adequacy. The cycle ends if the minimum number of clusters is reached and/or a deterioration of the model's adequacy (clustering error increase) is determined.

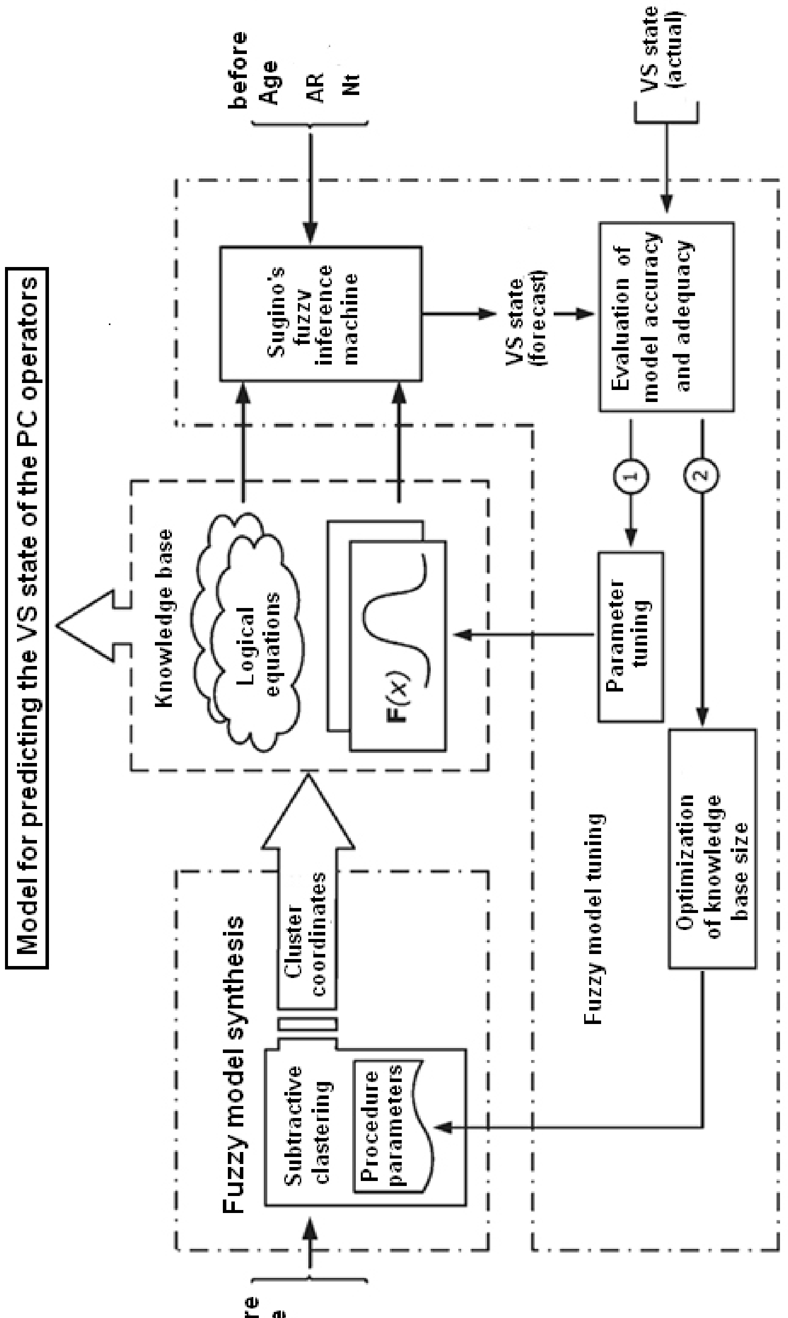

Fig. 1. Process diagram of synthesis and adjustment of the prediction model the PC operators' VS state (1 and 2 are the primary and secondary ways to tuning procedure)

The number of equations required is obtained by tuning the model. The model describes a primary data set, the number of equations can be from 1 to ∞, and the more equations, the more accurate the result of clustering, but a large number of equations greatly increase the volume of calculations. Therefore, changing the parameters of the mountain clustering algorithm achieves the minimum number of equations at the minimum of the prediction error.

According to the training sample, we obtained a fuzzy model consisting of six fuzzy logic equations, six fuzzy rule membership functions (which estimate the corresponding initial variable) approximated by a Gaussian function, and six linear functions in fuzzy rule conclusions. The knowledge base rules of the fuzzy model obtained correspond to the system of fuzzy logical equations:

$$\mu^1_{FSVS}(X) = \mu^1_{Age}(x_{Age}) \wedge \mu^1_{AR}(x_{AR}) \wedge \mu^1_{Nt}(x_{Nt})$$

$$\mu^2_{FSVS}(X) = \mu^2_{Age}(x_{Age}) \wedge \mu^2_{AR}(x_{AR}) \wedge \mu^2_{Nt}(x_{Nt})$$

$$\mu^3_{FSVS}(X) = \mu^3_{Age}(x_{Age}) \wedge \mu^3_{AR}(x_{AR}) \wedge \mu^3_{Nt}(x_{Nt})$$

$$\mu^4_{FSVS}(X) = \mu^4_{Age}(x_{Age}) \wedge \mu^4_{AR}(x_{AR}) \wedge \mu^4_{Nt}(x_{Nt})$$

$$\mu^5_{FSVS}(X) = \mu^5_{Age}(x_{Age}) \wedge \mu^5_{AR}(x_{AR}) \wedge \mu^5_{Nt}(x_{Nt}),$$

where $\mu^n_{FSVS}(X)$ is the degree of implementation of the fuzzy knowledge base rules for the initial vector of indicators; $X = \{x_{Age}, x_{AR}, x_{Nt}\}$ is the membership functions of the VS state indicator to the fuzzy term of the knowledge base.

Table 1 shows the vertices coordinates of the (b) of the fuzzy rule membership functions and the compression-stretching parameters of their branches (c), in Table 2 — coefficients of linear functions in the fuzzy rules conclusions.

Table 1. **Vertices coordinates of fuzzy rules (b_i) and the compression-stretching parameters of their branches (c_i)**

Rule No	Parameters of membership functions	Parameter values		
		Age	AR	Nt
1	b_1	32	5,605	8,253
	c_1	3,864	1,597	3,699
2	b_2	28,87	6,602	6,01
	c_2	3,84	1,627	3,808
3	b_3	26,92	1,69	5,628
	c_3	3,576	1,687	4,427
4	b_4	24	7,081	5,015
	c_4	3,713	0,5964	3,689
5	b_5	37,84	4,803	9,706
	c_5	3,939	1,653	3,388
6	b_6	30,08	1,007	8,38
	c_6	3,831	1,737	3,672

Table 2. **Coefficients of linear functions in the fuzzy rules conclusions**

Rule No	Product function parameters			
	Age	AR	Nt	Residual member
1	-3,764	6,516	-1,822	120,4
2	-2,844	5,028	-2,692	44,34
3	-0,4893	0,1561	-0,9229	13,57
4	0,3473	0,3161	0,117	-10,94
5	-0,8781	0,2846	0,2767	34,18
6	-1,001	2,371	-0,0518	35,83

To solve the tasks of preliminary data analysis and forecast model synthesis, we used the software package of the Scilab computer algebra system [23] with the sciFLT extension package [24]. The Scilab package was developed by the staff of the National Institute of Informatics and Automation (INRIA, France) and is distributed of charge under the free CeCILL license.

Fuzzy.dll software was developed to allow the use of a VS state fuzzy model without the need to install additional software (Scilab software package). It is a Dynamic Link Library (DLL) that implements COM (Component Object Model) [25] software model and contains the SugenoFuzzyIS class interface that defines basic functionality and a functions API set, create and manage COM objects.

The software implementation of the COM library interface, as well as the algorithms for downloading and converting fuzzy model files in Scilab/sciFLT format are original. The software implementation of the Sugeno fuzzy output algorithm is based on the freely distributed software library "FuzzyLogicLibrary for Microsoft .NET" [26]. Integrated Visual Studio Community Edition software development environment and Microsoft .NET Framework technology were used.

The built-in forecasting model is at the heart of the physician's decision-making support module, which allows the physician to work with a personal computer without Microsoft Office Professional. The free Microsoft Access Runtime [27] was used for this purpose. In this case, the interface is slightly different from the standard: there is no database window, no editing tools, and no standard panels.

METHOD FOR EVALUATION AND FORECASTING OF THE OPERATORS` FUNCTIONAL STATE UNDER VISUAL WORK

Based on the results of previous studies and the built-in forecasting model, a method of evaluation and prediction of the person` functional state and his visual system state has been developed, which includes two operation modes according to the tasks of evaluation.

The first mode is intended to identify individuals who may be at risk for developing visual astenopia. This mode of the method is used, for example, when recruitment/hiring for work with increased visual load. In the case of applying the first mode, the indicators of the VS functional state (AR of both eyes, Nt of both eyes) determine in the first step. In the second step, normalization of the obtained indicators is carried out. The possibility of the asthenopia development is evaluated in the third step using the proposed forecasting model. Algorithm based on model allows assigning the person to one of the clusters analyzed earlier.

At the final step, recommendations for correction of the detected operator`s state are provided. For this purpose, at first reaction of his visual system to the possible working visual load is predicted depending on the features of the cluster to which this operator is attributed. In accordance with the particular person` state tested for a particular cluster, recommendations are made on the prevention or treatment of a possible asthenopic state using the established criteria and the proposed classification of the asthenopic expressiveness complaints.

The second mode of developed method is intended for carrying out periodic medical examination of the persons engaged in visual work. In this case not only the indicators of the visual system, but also the asthenopia are defined in the first step. Also indexes developed using the methods of forming integral estimates [28, 29] are being analyzed.

In the second step, the normalization of the obtained indicators and determination of the proposed indexes, Index of Near Visual Information Acceptance (I_{NVIA}), accommodation (I_A), asthenopia severity index (I_{AS}), index of functional state of the visual system (I_{FSVS}) are doing:

$$I_{NVIA} = \text{Nt OD}_2/\text{ Nt OD}_{1o} + \text{Nt OS}_{2я}/\text{ Nt OS}_1 + \text{NCP}_2/\text{ NCP}_1\ ,$$

$$I_A = \text{AR OD}_2/\text{ AR OD}_1 + \text{AR OS}_2/\text{ AR OS}_1\ ,$$

$$I_{AS} = Igen + Ivis + Ioc, \qquad I_{\text{FSVS}} = I_{\text{NVIA}} + I_A\,,$$

where Nt OD_1, Nt OD_2, Nt OS_1, Nt OS_2 are the position of the nearest clear points (Nt) for the right (OD) and left (OS) eyes; NCP_1, NCP_2; AR OD_1, AR OD_2, AR OS_1, AR OS_2 — accommodation reserves; characteristics are given before (1) and after (2) visual load.

In the third stage, the person is referred to a specific cluster using a developed model, that allows to predict changes in his functional state in the case of a given visual load. Further analysis and comparison of the current functional state with the previous one are done, three variants of changes are obtained namely: 1) unchanged, 2) improvement or 3) deterioration of the state, also additional information on the effectiveness of the carried out preventive measures is received. The improvement of the state indicates the corrective measures effectiveness and the adequacy of visual load to capabilities of the operator` visual system. The first and third options require more careful analysis.

CLINICAL DECISION SUPPORT SYSTEM FOR ANALYZE AND PREDICT OPERATOR` FUNCTIONAL STATE

The proposed method is implemented in clinical decision support system (CDSS) for analyze and predict changes in the operator's VS due to visual work. The automated system consists of the patient registration module, the module of the results of ophthalmological examinations and the patient's state subjective assessment, the decision support module for the physician and the database (Fig. 2).

Finally, recommendations for improving the visual system FS are provided or corrected. If, as a result of preventive measures, the state worsen or does not improve, then the measures taken are either ineffective or patient does not fulfill the physician's prescription.

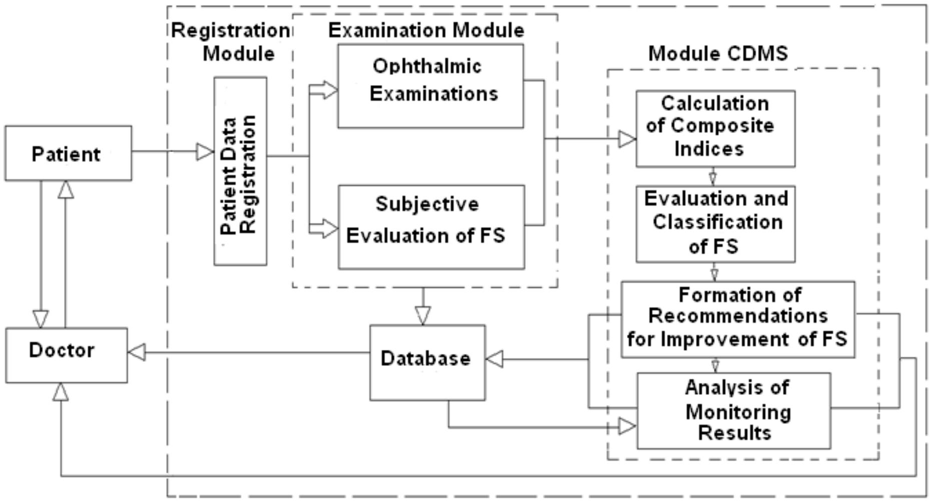

Fig 2. Structural and functional diagram of clinical decision support system

Supporting physician decision-making with the help of a developed CDS system is to assess functional state based on objective and subjective characteristics, to classify this state (based on a predictive model) and to form recommendations for its correction. An important function is to provide the ability to monitor patients' functional status changes.

RESULTS OF CLINICAL DECISION SUPPORT SYSTEM USE

For the testing of the developed CDSS the group of 30 PC users was formed who complained about the visual system FS in the Kharkiv City Clinical Hospital №14 named after Prof. L.L. Girshman and agreed to participate in the study. Young adults with a visual acuity of 0.9–1 and physiological astigmatism not exceeding 0.5 D were selected. The patients` average age was (26.6 ± 3.7) years.

For all patients, AR of both eyes, distance Nt of both eyes and NCP was determined. Patients also answered the questionnaire to determine the asthenopic complaints expressiveness. In the first coming to physician, all patients were asked to perform a test with visual load for 45 min. (correction of a table with 30 line letters of the Cyrillic alphabet implemented on the monitor screen). After work, the patients` FS were re-determined.

According to the initial and final FS indicators the patients were divided into two clusters with use of the developed system. The first cluster included 53 % (16 persons), the second — 47 % (14 persons). The mean age of the patients in the first cluster was (25.8 ± 2.6) years, in the second — (27.8 ± 4.5) years. Performing a test task on a computer caused various changes in the clusters indicators, although significant differences between them remained.

In the first cluster, visual load caused an increase in AR and some decrease in Nt and NCP. In the second cluster, AR remained virtually unchanged, Nt and NCP increased. The initial and final indicators values in the clusters were compared and the frequency of occurrence of their different ratios was calculated (Table 4). The reliability of differences in the indicators changes frequency was evaluated using the criterion $\chi 2$ (significance level $p < 0.05$).

Table 3. **Mean VS state values of patients in two clusters**

Registration conditions	Cluster	Indicators				
		AR OD	AR OS	Nt OD	Nt OS	NCP
Before	1 (n=16)	5,7±1,5	5,1±1,5	6,3±1,2	6,1±1,1	5,7±1,0
	2 (n=14)	3,0±1,5*	2,8±1,8*	7,9±1,6*	7,7±1,1*	7,2±1,2*
After	1(n=16)	6,2±1,4	6,0±1,1	5,7±0,9	5,9±1,0	5,8±0,9
	2(n=14)	3,1±1,5*	2,7±1,8*	8,6±1,0*	8,4±0,8*	7,7±0,9*

Note: * — differences between the mean values of the first and second clusters are significant according to the Mann-Whitney criterion ($p < 0.05$).

Table 4. **Distribution of patients according to the VS indicators depending on the nature of their changes due to visual work of AF**

Cluster	Nature of changes	Amount of patients according to the VS indicators		
		AR	Nt	NCP
1	Unchanged	3(19±9,8)[3] $\chi^2 = 8,1$	1(6±5,5)	4 (25±10,8)
	Magnification	11 (69±11,6)[1] $\chi^2 = 4,5$	4 (25±10,8)* $\chi^2 = 8,6$	7 (44±12,4)
	Reduction	2 (12±8,1)	11 (69± 11,6)[2] $\chi^2 = 4,5$	5 (31±11,6)
2	Unchanged	5 (36±12,8)	2 (14±9,3)[3] $\chi^2 = 11,6$	2 (14±9,3)[3] $\chi^2 = 11,6$
	Magnification	5 (36±12,8)	11 (79±10,8)[1] $\chi^2 = 9,1$	11 (79±10,9)[1] $\chi^2 = 9,1$
	Reduction	4 (28±11,2)	1 (7±6,5)* $\chi^2 = 11,8$	1(7±6,5)* $\chi^2 = 11,8$

Notes: * — differences in the frequency of occurrence of a VS indicator change between the first and the second cluster are significant; 1 — differences in the frequency of the indicator growth and other changes are significant; 2 — differences in the frequency of index decrease and other changes are significant; 3 — differences in the frequency of indicator growth and its stable value are significant in the cluster.

In the first cluster, there are significantly more changes with increase in AR and decrease in Nt, which indicates that transient myopia occurs in 69 % of the tested patients in this cluster. Therefore, the first cluster can be called myopic. In the second cluster, 79 % of patients showed an increase in Nt and NCP against maintaining or decreasing AR values (64 %), which is characteristic of visual fatigue; this cluster can be called a visual fatigue cluster.

All patients — PC users, according to their visual functions and the asthenopic complaints expressiveness degree were given individualized recommendations for their correction.

A re-examination of the visual features of PC users was conducted one month after the appointment of the recommended measures. The visual component of asthenopic complaints expressiveness in the first cluster decreased in 51 % of patients, in the second — in 50 %. The degree of ocular component of asthenopic complaints expressiveness decreased in 25 % of patients in the first cluster and in 58 % of patients in the second cluster. The results obtained indicate an improvement in the patients` overall state as a result of effective recommendations for its correcting.

Due to the effective functional state correction, it is possible to transfer the patient from the cluster with requiring medical measures to the cluster with the best indices, persons of this cluster should only be observed the modes of work and rest. The reverse situation is also possible, when the VS indicators are deteriorating and the degree of asthenopic complaints expressiveness increases, which leads to a deterioration of the overall patient`s functional state. In this case, in addition to the medical and optical correction of the existing problem, the explanatory work with patient should be carried out. The doctor should find out the causes of the deterioration and help optimally correct the visual activity (not only in the work, but also in everyday life), which is also an effective measure for the prevention of patient`s health further reduction.

CONCLUSIONS

Constructed model for predicting visual system changes in consequence of visual work, which includes a functional indicators complex of the visual system and is based on the algorithm of fuzzy clustering (c-averages) and the system of fuzzy Sugeno inference, allows to cluster the data for the division of the tested persons into two subgroups, which revealed different mechanisms of visual work influence on the person`s functional state.

The use of the developed clinical decision support system for assessment and prognosis of the patients' state, as well as recommendations for individual correction of their present state made it possible to improve visual functions in 67 % of patients, reduce the general complaints expressiveness in 50 % of patients, visual complaints expressiveness — in 53 % of patients, and eye complaints expressiveness — in 40 % of patients.

In view of the asthenopic influence on the operator`s general functional state and on the quality of work tasks performance, it would be advisable to assess the candidate's tendency to develop visual asthenopias during the professional selection for operator specialties. If a candidate is prone to such conditions, there are two possible ways to solve the problem: to recommend either a choose a profession associated with less visual load, or an individual program to correct the existing visual system state and prevention of visual astenopy. This program includes appropriate optical correction, medication, appropriate eye exercises and visual system exercises.

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МОДЕЛЬ І МЕТОД ОЦІНЮВАННЯ ТА ПРОГНОЗУВАННЯ ЗМІН ФУНКЦІОНАЛЬНОГО СТАНУ ЗОРОВОЇ СИСТЕМИ ВНАСЛІДОК ЗОРОВОЇ ПРАЦІ

Вступ. Під час розумової праці 90 % інформації сприймається зоровою системою (ЗС) людини, тому ефективність діяльності істотно залежить від якості функціонування ЗС та типу носіїв візуальної інформації, особливо нетрадиційних (телевізор, монітор персонального комп'ютера, мініатюрні дисплеї мобільних телефонів, електронні книги). Тривалі інформаційні перевантаження можуть призводити до формування таких станів, як хронічний стрес, синдром хронічної втоми, невроз, професійне «вигорання» та астенопія, які погіршують функціональний стан (ФС) оператора, впливають на якість виконання виробничих завдань, тривають довгий час і вимагають спеціальної корекції і лікування.

Метою роботи є розроблення методу оцінювання та прогнозування функціонального стану операторів на основі моделі прогнозування змін стану зорової системи за умов зорової праці, а також реалізації методу в автоматизованій системі підтримки прийняття рішень лікарем для аналізу стану ЗС оператора внаслідок зорової праці.

Результати. Обґрунтовано необхідність визначення однорідних груп досліджуваних за допомогою кластеризації отриманих даних та визначено два кластери. Побудовано модель прогнозування змін стану ЗС внаслідок зорової праці за комплексом показників функціонального стану зорової системи з використанням алгоритму нечіткої кластеризації (*c*-середніх) та системи нечіткого виведення Сугено. За результатами попередніх досліджень та побудованої прогнозної моделі розроблено метод оцінювання та прогнозування функціонального стану людини та її зорової системи. Запропонований метод реалізовано у автоматизованій системі підтримки прийняття рішень лікарем для аналізу та прогнозування змін стану ЗС оператора внаслідок зорової праці.

Висновки. Використання запропонованого методу та автоматизованої системи дає змогу прогнозувати зміни стану ЗС у разі заданого зорового навантаження, порівнювати поточний функціональний стан з попереднім, одержувати інформацію про ефективність рекомендованих профілактичних заходів. За результатами апробації розробленої системи визначено, що використання цієї системи оцінювання та прогнозування функціонального стану оператора, а також рекомендацій щодо індивідуального корегування наявного стану уможливило поліпшення зорових функцій у 67 % пацієнтів, знизити ступень виразності загальних скарг у 50 % осіб, зорових скарг — у 53 %, очних скарг — у 40 % пацієнтів.

Ключові слова: функціональний стан зорової системи, зорове навантаження, модель прогнозування стану зорової системи, астенопія, нечітка кластеризація, система підтримки прийняття рішень лікарем.

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МОДЕЛЬ И МЕТОД ОЦЕНКИ И ПРОГНОЗА ИЗМЕНЕНИЯ ФУНКЦИОНАЛЬНОГО СОСТОЯНИЯ ЗРИТЕЛЬНОЙ СИСТЕМЫ ВСЛЕДСТВИЕ ВИЗУАЛЬНОЙ РАБОТЫ

Построена модель прогнозирования изменений состояния зрительной системы вследствие зрительной работы, которая базируется на комплексе показателей функционального состояния зрительной системы с использованием алгоритма нечеткой кластеризации (с-средних) и системы нечеткого вывода Сугено. По результатам предыдущих исследований и построенной прогнозной модели разработан метод оценки и прогнозирования функционального состояния человека и его зрительной системы. Предложенный метод реализован в автоматизированной системе поддержки принятия решений врачом для анализа и прогнозирования изменений состояния оператора в результате зрительной работы. Использование метода и автоматизированной системы позволяет прогнозировать изменения этого состояния в случае заданной зрительной нагрузки, сравнивать текущее функциональное состояние с предыдущим, получать информацию об эффективности рекомендованных профилактических мероприятий. По результатам апробации разработанной системы определено, что использование системы оценки и прогнозирования функционального состояния оператора, а также рекомендаций по индивидуальному корректированию имеющегося состояния позволило улучшить зрительные функции у 67 % пациентов, снизить степень выраженности общих жалоб у 50 % лиц, зрительных жалоб — у 53 % , глазных жалоб — у 40 % пациентов.

Ключевые слова: функциональное состояние зрительной системы, зрительная нагрузка, модель прогнозирования состояния зрительной системы, астенопия, нечеткая кластеризация, система поддержки принятия решений врачом.