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The Study Of Vehicle Driver Psychophysical Condition.

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ABSTRACT

One of the key problems of labor productivity increase in agriculture is the control and the management of agricultural machinery operation efficiency in various climatic conditions by improving the ergonomic conditions of an operator and other factors that maximize the approach of working conditions to the most comfortable state for a long time during seasonal work. To solve the problem, the article proposes to evaluate the intensity of the psychophysical state and to decide on the necessity and the timeliness of the corresponding relaxation effects according to a certain scale. They provide the mathematical dependences between the main factors of the influence on an operator and his sensations obtained experimentally under laboratory conditions. They propose the technique to estimate tension in the case of simultaneous impact of several factors. The conclusion is made about the predominance of the neuropsychic load in the self-esteem of comfort level. It is proved that the absence of unfavorable factors of one type contributes to the improvement of comfort (the reduction of an operator psychophysical state) with the presence of different type factors. The mathematical regularities and scales are given, which allow to automate the calculation of the tension estimate. The results of research can be used both in agricultural machinery ergonomic characteristic and in work condition improvement, including the psychological microclimate.
Keywords: agricultural equipment, operator ergonomics, tension, mental and physical state.

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INTRODUCTION

The main feature of agricultural worker professional activity is the seasonal fluctuations of labor intensity and labor load [2]. The work in the field implies that an operator of agricultural machinery is in critical climatic conditions (temperature, dust, high vibration, etc.). In this case, a sharp increase of labor productivity is required as a rule. In this regard, the study of the psychophysical state of drivers in the simulation models is an actual problem of the most acceptable condition achievement for a driver comfort in the field conditions as an integral part of the biotechnical system (BTS) "operator-vehicle".

According to [8, 16] the ergonomic properties of the vehicle are the system-forming factor that determines the level of operator's psychophysical energy costs, the degree of his fatigue - which affects the safety of work [11, 15]. The issues of the operator's place ergonomics are constantly in the focus of theoretical and practical research attention [1,6,12,14,19,20,21]. The achievements in this area are reflected in engineering solutions, fixed in regulations and standards (for example, [17]).

Knowing the models of the ergonomic characteristic perception by an operator of a certain mode of transport under the assumed operating conditions of the operator, it is possible not only to increase comfort, but also to reduce the likelihood of an emergency situation related to the human factor.

In this regard, the aim of the study is to synthesize an imitative mathematical model that allows to predict the values of the driver's comfort indicators based on experimental data.

MATERIALS AND METHODS

Simulation mathematical model in general form can be considered as a system of interrelated particular regularity models between the factors of influence and induced sensations.

The analysis of information sources [5, 1, 12, 16, 22] made it possible to identify the following system-forming ergonomic factors characterizing the operators of agricultural machinery: the noise in a booth, microclimate parameters in a booth (temperature, humidity), physical load on various controls (steering wheel, levers, pedals), anthropometric parameters of an operator's seat, vibration (general and local one), neuro-psychic load.

During the simulating studies on simulators, the methodology of psychophysiological comparative scaling was used [3, 13, 9], according to which a subject evaluates the intensity of action sensations of external sensory stimuli numerically, using a certain reference sensation, taken for 10 points.

The experiment on psychophysical noise scaling used a fixed standard with the intensity of 65 dB. In the absence of standards, the subject was recommended to take the value corresponding to the most comfortable sensation. The studies on noise intensity psychophysical scale were carried out in a special soundproof chamber (chair, microphone, speakers, audiometer, the noise was generated in the range of 65 - 90 dB with a step of 5 dB).

In order to study the psychophysical scaling of the temperature factor estimation, a heat-insulated chamber was used (the temperatures varied in the range [20 °C, 45 °C] with the step of 5 °C.

The scaling of physical load level on the steering wheel was carried out on a specialized stand (a rudder simulation with the load from 0 to 30N and the increment of 5N).

The study (scaling) of anthropometric indicators was carried out on a device that allows you to change the back inclination angle (10, 15, 20, 25, 30 degrees from the vertical).

In order to assess the level of neuropsychic load, Piorkovsky's apparatus was used [7] (the attention distribution was tested).

The analysis of literature sources [4, 11, 18] allowed to form the following universal classification table to estimate a driver's tension level by various factors.

Table 1: Vehicle driver tension

Level of tension	Tension level characteristic	The purpose of body autonomous system functioning	Feedback domination	Management advice
1. Norm state	The absence of functional state shifts. Highly stable relationships of system functions. The normal level of inter-system integration regulatory mechanism tension.	*Homeostasis*	Negative	The vehicle is operated normally
2. Risk group	Minor changes of the functional state. Insignificant increase of tension level in the regulatory mechanisms of inter-system integration.	*Self-organization*	Negative	A short break in management is required (rest)
3. Condition of the 1st degree of tension	A moderate increase of voltage level and the mismatch of the inter-system integration regulatory mechanisms.	*Self-healing, small fluctuations ("prowling")*	An unstable balance "point" of negative and positive	1-2 hour break in management is required (rest)
4. Condition of the 2nd degree of tension	Expressed changes of the functional state, tension and the mismatch of intersystem integration regulatory mechanisms.	*Transition to a new state with recovery and bifurcation capabilities, large fluctuations*	Positive	The termination of work and-or an operator change or 1-2 day break is required
5. Condition of the 3rd degree of tension	Sharply expressed changes in the functional state. High level of tension and the mismatch of intersystem integration regulatory mechanisms.	*Transition to a new state without the possibility of recovery, bifurcations are almost absent, there are no fluctuations*	Negative - "fixing" the new states	The suspension of an operator from control, minimum relaxation period is one week.

OThe stress Hi evaluation of the vehicle operator functional state according to the factor *i* is carried out according to the following formula:

$$H_i = \log_{2(\pi \cdot \frac{y_i^*}{y_i^0})}, \qquad (1)$$

Where y_i^0 is the reference value of the i-th factor subjective sensation, corresponding to the comfortable state, y_i^* - the fixed value of the factor in the management of agricultural machinery (vehicle).

Based on the hypothetical principle of the "golden section" of quantitative change accumulation for the transition to a new qualitative state, the application of the formula (1) allows to suggest the following correspondence of Hi stress value to different clusters (Table 1) - presented in Table 2.

Table 2: Stress levels

№	Value H_i (upper limit)	The degree of regulatory system tension	State cluster according to table 1
1	1.38	Optimal level (norm)	State of the norm
2	1.62	Normal level	State of the norm
3	2,38	Moderate stress	Risk group
4	2,62	Severe stress	1st degree of tension
5	3,38	Sharply expressed stress	2nd degree of tension

6	3,62	Overstrain	2nd degree of tension
7	4,38	A marked overstrain	3rd degree of tension
8	4,62	The depletion of regulatory systems	3rd degree of tension
9	5,38	Sharply expressed depletion of regulatory systems, destructive changes	The ultimate tension (a possible point of "non-return" from irreversible destructive changes)
10	>6	Destructive depletion of regulatory systems	"Out of limit" tension (irreversible destructive changes)

If the simultaneous impact of several factors is observed, then they propose to evaluate the level of the integrated intensity IH according to the following procedure:

1. The stress is determined for each active factor H_i;

2. The lower limit $IHmin$ is determined:

$$IHmin = \sqrt[n]{\prod_{i=1}^{n}(H_i)}; \qquad (2)$$

3. The upper limit $IHmax$ is determined:

$$IHmax = \sqrt[n]{\sum_{i=1}^{n} H_i^{\,n}}, \qquad (3)$$

Where n is the amount of considered factors;

4. For the obtained boundaries, the predictions are evaluated according to possible situations (see table 1, 2) and a decision is taken on various relaxation measures.

Formula (3) is characteristic for orthogonal arguments. Meanwhile, between the sensations of various factors i and j impact, there are the connections characterizing pair correlations $RH_{i,j}$ by a certain matrix, at that the matrix elements can be estimated both empirically and theoretically, knowing the mathematical models of impact perception and conducting an imitative modeling. In this case, the upper limit is estimated by the following formula:

$$IHmax = \max\left(IHmin, \sqrt[n]{\sum_{i=1}^{n} H_i^{\,n} - \sum_{i=j+1}^{n-1}\left(\sum_{j=1}^{n}\left(H_i^{\,n/2} \cdot H_j^{\,n/2} \cdot RH_{i,j}\right)\right)}\right). \quad (4)$$

DISCUSSION OF RESULTS

The processing of the experimental material (63 volunteers) made it possible to reveal the following patterns between the intensity of acting factors and the subjective evaluation of sensations by the proposed metric (10 points - comfort state):
- noise intensity estimation:

$$\log(ys) = 0{,}33 + 0.3 \cdot \log(xs) \qquad (5)$$

(the variability of the function parameters was 8%);
- thermal sensation evaluation:

$$\log(yt) = 0.28 \cdot \log(xt) \qquad (6)$$

(the variability of the function parameters was 4%);
- the estimation of physical load on controls:

$$\log(yu) = 0.62 + 1.28 \cdot \log(xu) \qquad (7)$$

(the variability of the function parameters was 15%);
- the evaluation of the of the driver's seat back angle change:

$$\log(ya) = 0.2 + 1.6 \cdot \log(xa) \quad (8)$$

(the variability of the function parameters was 5%);
- the evaluation of neuropsychic load level, revealed on Piarovsky's device:

$$\log(yp) = 2.3 \cdot \log(xp) \quad (9)$$

(the variability of the function parameters was 5%).

(xs and ys, xt and yt, xu and yu, xa and ya, xp and yp are the effects of noise, heat, controls, back inclination angle, neuropsychic load and the subject sensations from them.

Consequently, without taking into account the correlation relationships, we obtain the formulas to estimate the level of the strains Hi, respectively (according to formula (1)):

$$H_s = -0{,}41 + xs^{0.3}, \quad (11)$$

$$H_t = -0.67 + xt^{0.28}, \quad (12)$$

$$H_u = -0.133 + xu^{1.28}, \quad (13)$$

$$H_a = -0.52 + xa^{1.6}, \quad (14)$$

$$H_p = -0.67 + xp^{2.3}. \quad (15)$$

The obtained formulas (11) - (15) represent an imitation model that allows to estimate a possible degree of agricultural machinery operator tension predicting the values of various factors, x.

CONCLUSIONS

The analysis of the obtained dependences allows us to draw the following conclusions:

1. The degree of agricultural machinery operator state tension increases with the growth of influence factors on a body, at that the noise intensity and the temperature factor act more smoothly and are increased with approximately the same speed;

2. The most powerful effect on an operator's condition is provided by neural-physical loads (close to parabolic increase);

3. The absence of the studied factors of influence contributes to the state general tension reduction;

4. As the degrees of influence increase, the factors are ranked as follows: "heat sensations", "noise intensity", "load on controls", "seat angle" and "neuropsychic load".

Thus, the increase of the neuropsychic load on the operator (including the increase of recorded information number (devices) and/or the absence of local relaxation acts (music in a booth or encouraging - stimulating a short-term conversation-phrase, for example) is able to bring to naught all ergonomic improvements achieved as the result of noise reduction, the use of climate control systems, controls and an operator's pose. And conversely, the reduction of neuropsychic stress intensifies the feeling of comfort under adverse physical conditions.

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