Study of performance and assessment of the state of higher nervous activity of the human operator in the "man-display" system

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Abstract. The paper discusses the psychophysiological characteristics that describe the state of the nervous system of a human operator when working with a display. Special attention is paid to such characteristics of the nervous system as emotional stability and information transmission rate in the oculomotor system. Methods for measuring these characteristics using digital and literal texts are presented. The measurements were performed using a device developed by the author. The results of the performed experiments make it possible to solve the problem of occupational selection of operators with appropriate characteristics.

1. Introduction
The efficiency and reliability of the functioning of a complex man-machine system largely depends on the psychophysiological state of a person. In this regard, the problem of occupational selection of operators based on their personal qualities, which consider the individual characteristics of the nervous system, emotional stability, the rate of information transfer in the oculomotor system, is of great importance. This is especially important when working with a display. The solution to this problem is greatly simplified if the process of obtaining the psychophysiological characteristics of a human operator is automated.

In the occupational physiology and psychology, there are many different methods for assessing the mental and physiological state of a person, as well as his/her performance [1–3]. The most sensitive among them are those that use digital and literal tests [3]. A distinctive feature of these tests is simplicity and dynamism.

The study of such important human physiological function as attention is of great interest. Attention shifting is the intentional moving of attention from one object or activity to another. Characteristic of attention shifting is the degree of difficulty of its implementation measured by the rate of the subject’s transition from one activity to another. It has been established that the rate of attention shifting depends on both the stimulus material and the nature of the subject’s activities Attention is the focus of mental activity on certain objects or phenomena of reality (objects of perception) [1]. Involuntary attention arises without any intention, without a predesignated specific goal and does not require any conation. Voluntary attention arises from a consciously set goal and requires certain conation. Attention is not found in the "pure" form, it is always functionally directed towards something. Attention determines the selectivity,
conscious or semi-conscious selection of information incoming through the sense organs. Unlike other cognitive processes (such as perception, memory, thinking, etc.), attention does not have its own special content, it appears as though inside these processes and is inseparable from them.

Experimental study of attention is one of the most important for practice areas of research of psychophysiological characteristics of a human operator. When the attention is described as a complex mental phenomenon, the following of its properties are specified: capacity, concentration, division, stability, distractibility, fluctuation, shifting, selectivity [1]. The capacity of attention is measured by the number of objects that can be clearly perceived at the same time (in a relatively short period of time). For an adult human, it is usually equal to 6-8 objects. Concentration is the degree of focusing the mind on an object (objects) in the presence of interference. Division of attention is expressed in the ability to simultaneously perform several actions or to observe several processes, objects. Stability of attention is the overall direction of attention in the process of the activity. Its main characteristic is the duration of maintaining the direction and focus of mental activity without departure from the initial level. The opposite of stability property is fluctuation. Fluctuation is a repetitive involuntary distraction, inattention to a given object or activity connected with it. The ease or difficulty of attention shifting is also determined by the individual characteristics of the subject, namely by the properties of his/her nervous system. For those with "quick-acting" nervous system (the rapid transition from excitation to inhibition and vice versa), attention shifting is easier to perform. The personal characteristics of the subjects, namely: their activity and personal interest, level of motivation, etc. are not less significant.

Attention selectivity is selection of some signals from many others. It is a complex characteristic: it includes both quantitative and qualitative parameters. The quantitative parameter of the selectivity of attention is the rate at which the subject selects a stimulus from among many others. The qualitative parameter is the accuracy, i.e. the degree of compliance of the results of the selection with the original stimulus material.

Intense sustained attention is required of the human operator, while working with the display. Important qualities of attention are its range, its fast dividing and fast switching. Attention switching takes place when the gaze is shifted from object to object. The slowness of attention is weak. People with a strong nervous system and mobility of processes of excitation and inhibition quickly switch to a new object, i.e., they have sustained attention. It is known [4] that there is a correlation between indicators of the mobility of nervous processes and attention. To study the characteristics of attention, Platonov table consisting of numbers of different colours is used. The subject should name the numbers of one colour in ascending order, and numbers of the other colour — in descending order. The task performance time and the number of errors are estimated [5].

The purpose of the paper is to assess the performance and state of the human nervous system using psychological tests.

2. Materials and methods
One of the most common ways to study the state of the nervous system is the method using the test table of V. Ya. Anfimov [3]. It contains 1200 letters of the same size equally spaced from each other. The letters in the table are arranged without any connection, thus, the possibility of memorisation is excluded, and a great concentration of attention is required when performing a task. The operator (subject) is given a task: to cross out a letter, for example "a". The
work goes on for several minutes, the end of each minute is marked by the experimenter; then the subject is given 2–3 minutes for rest and the research is repeated 2–3 times. The subject’s work is assessed by the number of errors made and by the time spent on the task performance. This technique allows you to assess the state of the nervous system (higher nervous activity) by several indicators:

a) external inhibition — a distracting signal is given after 2–3 minutes of work. As a result, work slows down, and performance is degraded;

b) internal inhibition: 1) to cross out the letter "m"; 2) to cross out "m", but if it is preceded by "n", then not to cross it out. The number of skips and errors will be an indicator of internal inhibition;

c) delayed inhibition — to cross out the letter located two or three letters after each letter "k". The greater the distance between letters, the more difficult the task.

Crossing out similar letters, increased reaction to external irritants, non-observance of the internal inhibition processes indicate the predominance of the excitatory process. Slow work, an increase in the number of errors — missing letters — indicate the predominance of the inhibitory process. If these disturbances are observed after operating activities, then they are signs of fatigue.

One of the important psychophysiological characteristics of a human operator is the rate of information transfer in the visual system. To study this characteristic, a test table with Landolt rings is used. There are 660 randomly arranged rings in the table, each with a gap in one of eight possible directions. The subject is given the task: to look through the table and count the number of rings with a certain direction of a gap. The number of missing rings and the time spent looking at the table are estimated. According to these indicators, it is possible to approximately determine the information transmission rate in the visual-motor system by the formula [3]:

$$V = \frac{0.5936N - 2.807n}{T},$$

where $V$ — speed of perception and processing of information in bit/sec;

$T$ — time spent on the task;

$N$ — number of counted rings;

$n$ — number of errors (missing rings).

From the considered methods for assessing the psychophysiological characteristics of a human operator, it follows that they are all based on counting the errors made by the subject and the time spent on the task performance. This allows you to automate psychophysiological studies. For this purpose, the author has developed a device for psychophysiological research [6, 7].

These indicators are measured using a device containing an electric probe 1, subject’s console 2, switching unit 3, logical counter 4, unit for shaping pulses for correct actions of a subject 5, error pulse shaping unit 6, time counter control unit 7, unit for shaping the pulses of subject’s operation 8, registration unit 9 containing error counter 11, time counter 12, indicators of logical counter 13, and control unit 10. The block diagram of the device is shown in Figure 1.

The counter counts the total time spent on the performance of the task. When the subject takes the correct action (presses the desired contact), logical counter 4 is triggered by the second pulse and the indicator of this An alphabetic or some other test table is installed on the subject’s console. The subject should perform the task of finding a certain letter, for example, "a", and press the contact under this letter with an electric probe. Out of the 468 contacts, 50 are enabled corresponding to the letter "a". Before starting work, the device is reset to its initial state using unit 10. The time and error counters are set to zero, the setup indicator is on. When the subject presses the contact of the front panel of the subject’s control console with the electric probe, two pulses are received from the electric probe. One pulse arrives at unit 8 and then, through unit 7, triggers the time counter 12. As soon as the subject presses the last enabled contact, the
Figure 1.

logical counter 4 stops the time counting through unit 7. counter lights up in unit 9. As a result of the interaction of pulses of units 6 and 8, there is a constant voltage at the output of unit 6. It will not trigger the error counter 11 in unit 9. Simultaneously with the start of time counting, the indicator of the logical counter lights up if the subject has not made an error. If the subject makes an error (for example, misses the desired contact), a pulse will be shaped in the logical counter 4 and in unit 6 that will trigger the error counter. In addition, the indicator of the logical counter will not light up. The subject can see that he/she made an error. He/she should correct the error (the next indicator of the logical counter in unit 9 lights up) and continue working.

3. Results and discussion
Using this device, the state of the nervous system of a group of subjects was investigated using the Anfimov test table consisting of 468 letters. The subject is given the task: to find a specified letter and press under this letter with an electric probe [5]. Out of the 468 contacts, 50 are involved, corresponding to the given letter. The task performance time and the number of
errors are measured. The studies were repeated at least three times with each subject; students aged 20–25 participated in the experiment. As an example, table 1 shows the results of the work of 3 subjects with the Anfimov test table. According to the known technique [3], from the measurements taken, it is possible to draw a conclusion about the state of higher nervous activity, namely, the excitatory process predominates in the case of the subject Z.K, and the inhibitory process predominates in the case of the subject V.P. Table 1 shows that the subject Z.K. spends, on average, 50.6 seconds to perform the task and commits, on average, about 1 error. The subject V.P. spends, on average, 122 seconds to perform the same task, i.e., 2.4 times more, and commits 5 errors on average.

Table 1. The results of working with the Anfimov test table.

| Subject | No. | Time spent to perform the task (in sec) | Number of errors made |
|---------|-----|---------------------------------------|-----------------------|
| Z.K.    | 1.  | 60                                    | 2                     |
|         | 2.  | 50                                    | 1                     |
|         | 3.  | 42                                    | 1                     |
| B.V.    | 1.  | 78                                    | 2                     |
|         | 2.  | 99                                    | 3                     |
|         | 3.  | 105                                   | 3                     |
| V.P.    | 1.  | 110                                   | 5                     |
|         | 2.  | 102                                   | 4                     |
|         | 3.  | 154                                   | 7                     |

The rate of information transfer in the visual-motor system was studied with the help of the device under consideration and using the Landolt test table. The subject should look through the table and press the contacts placed under the rings with a certain direction of a gap with the electric probe. Out of 468 contacts, 60 are involved. The task performance time and the number of missing rings are estimated. According to these indicators, the rate of information transfer in the visual-motor system is determined by the formula (1). The measurements were repeated at least three times with each subject; students aged 20–25 took part in the experiment.

As an example, table 2 shows the results of the work of subjects with the test table with Landolt rings. The subject K.N. has a higher rate of processing and transmission of information in the visual-motor system (on average, 1.262 bit/sec for three dimensions) compared to the subject S.V. (0.75 bit/sec on average). The subject K.N. makes fewer errors and spends less time on the task. Some subjects had the rate of transmission and processing of information of about 0.5 bit/sec; such subjects showed a predominance of the inhibitory process in the study of their state of higher nervous activity.

The considered methods of psychophysiological research solve the problem of diagnosing the state of a human operator in a complex man-machine system and occupational selection of operators with appropriate characteristics. In addition, using the methods considered, the performance of the human operator is assessed, and signs of fatigue are identified. Together, these can help prevent human-factor accidents.
Table 2. Results of working with the Landolt test table.

| Subject | No. | Time spent to perform the task (in sec) | Number of errors made | Information processing rate (bit/sec) |
|---------|-----|---------------------------------------|-----------------------|--------------------------------------|
| K.N.    | 1.  | 22.8                                  | 1                     | 1.205                                |
|         | 2.  | 20.0                                  | 1                     | 1.344                                |
|         | 3.  | 21.7                                  | 1                     | 1.238                                |
| S.V.    | 1.  | 30.0                                  | 1                     | 0.896                                |
|         | 2.  | 32.5                                  | 2                     | 0.741                                |
|         | 3.  | 35.0                                  | 3                     | 0.607                                |

4. Conclusion
The task of studying the state of the nervous system and assessing its influence on the performance of a human operator is substantiated. For these studies, a method containing letters is used, namely, the Anfimov test table. The use of this technique makes it possible to assess the state of the nervous system by the following indicators: external inhibition, internal inhibition, and delayed inhibition. To study the rate of information transfer in the oculomotor system, the Landolt test table containing rings with gaps was used. The formula for determining the rate of information transmission in the oculomotor system is given. The methods discussed are based on the calculation of operator’s errors and the time spent on the task. This allows you to automate psychophysiological studies. The author has developed a device for psychophysiological research. All experiments were carried out using this device. The paper presents the results of experiments, based on which it is possible to select the most efficient operators.

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