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PSYCHOLOGICAL EXPERIMENT ON COMPONENTS OF THE MEANING OF WORK

Moscow TEKHNIЧЕСКАЯ ЭСТЕТИКА in Russian No 8, 1978 pp 13-15

[Article by V. I. Batov, candidate of psychological sciences, All-Union Scientific Research Institute of Work Safety of the AUCCTU, and M. V. Yermolayeva, graduate student at Moscow State University: "Investigation of the Meaning of Functional States"]

[Text] One of the lines of investigation in human factors engineering and ergonomic study of objects of standardization involves raising the effectiveness of the activity of the operator. The goal of the investigation, finding psychological criteria for standardization of activities, has many levels. On the level of operations formalization is possible, in other words "a norm can be worked out for the method of performance of a concrete action so that the performance can be monitored and evaluated" [1, p 30]; but the internal aspect of the action, related to the goal function, has been assumed to be unformalizable, "and that is precisely why difficulties arise in standardizing operator activity" [1, p 34]. These difficulties result primarily from the fact that "the problem of measuring the individual indexes of inner activity in human factors engineering and ergonomics has hardly even been raised" [1, p 39]. The present article is devoted to a discussion of the possibility of objectively defining certain mechanisms of inner activity.

The picture of the dynamics of functional states in the form of emotional experiences can serve as an indicator of the functioning of the mechanism of inner activity. Thus, V. I. Medvedev devotes considerable attention to human emotional states, which are evoked by the way the person experiences his relationship to the external world and to himself [2]. We consider emotional experiences from the standpoint of the genesis and orientation of emotional states, which for a human being is a result primarily of the meaning of the activity being performed. Specifically, it is through this that the emotional aspects of functional states are determined by the objective interrelationships of the motive, goal of activity, and external and inner means [2].

In psychology the question of the meaning of the activity being performed is included in the problem of the human being's relationship to this activity. It is precisely the meaning that gives the phenomena of activity their subjective quality, that is it "creates a partiality in human consciousness" [3, p 153]. In human factors engineering the meaning is considered as a factor that distinguishes the objective conditions and form of activity from the subject's conceptual model. In this aspect the primary function of the meaning is shaping the conceptual model [4]. But personal meaning has two forms of existence. In the current investigation this factor is especially important because only a broadened understanding of personal meaning will make it possible to interpret the results of the experiment convincingly.

The situation in an experiment conducted earlier [5] envisioned preservation of the motive of activity with changing conditions for performance of the actions. According to the hypothesis that was adopted the researchers expected, and indeed found, that making the conditions of activity more complicated causes a transformation of the personal meaning as a result of changes in the mechanism of goal formation (the process of identifying intermediate goals), but not as a result of a change in the actual motive of the activity.

A natural continuation of this investigation would be to set up an experiment where the motive itself could be changed. But then the interpretation of the results of such an experiment would be difficult at the very least because "the relationship of the motive to the goal, to a certain condition or result of an action, may be reflected by a person in the same way that he reflects any other objective relationships of activity, and it remains somewhat unclear why the reflection of certain objective relationships fosters the onset of a specific psychological formation, personal meaning, but the reflection of others does not" [6, p 97]. In application to the conditions of our investigation, this idea can be made concrete as follows: the endeavor to give an operational definition [7, p 192] of the concept "personal meaning" runs into difficulty in predicting and/or interpreting the structure of personal meaning because analysis of the subsystem "motive-goal" does not tell which direction the change in the structure of meaning will go when there is a change in the quality of the motive of activity. Here we must deal with two forms of existence of personal meaning.

Personal meaning, which is a form of "sensory experience of motives," signals the connection between events or actions and satisfaction or failure to satisfy needs directly in the form of an emotional experience" [8, p 28]. Emotional experiences that express this meaning are, on the one hand, a mechanism of inner determination of activity with respect to motives; on the other, they are an "emotional correction" of behavior whose role is to bring the general orientation and dynamics of behavior into line with the meaning of the situation and the actions being performed in it from the standpoint of satisfying the subject's needs defined in the motives of the activity [9].

The emotions "notice " the significance of surrounding phenomena for the subject, "set" the tolerable level of functional expenditures, and with this goal "switch on" various vital and behavior regulatory mechanisms [10, 11]. Emotional experiences which embody personal meaning are the fabric of the subjective psychological content of functional states and express the active side of the needs that are concretized in the motives of activity.

On the other hand, "in concrete psychological terms the conscious meaning is created by the objective relationship, reflected in the mind of the person, of that which inspires him to action and that to which the action is directed as its immediate result" [12, p 292]; in other words, as a unit of consciousness, personal meaning may be realized in determined values. Becoming conscious of the meaning means becoming conscious of the motive and the relationship that binds the motive and the goal. It was precisely this reading of personal meaning that we had in mind in our earlier investigation [5]. This made it possible to use the apparatus of psycholinguistics to identify operationally the structure of personal meaning.

Personal meaning embodied in values plays a significant role in the process of forming mental states. The consciously realized, meaning-forming motive that has become a motive-goal is the foundation of individual (conscious) regulation of mental states. Evidence of this is found in the results of research which proved the significant role of the consciously realized motive in averting the state of "satiety" [13]. Similar results have been obtained in studying monotony under conditions of assembly line production [14]. When there is a conflict among motives of activity (extreme situations) the consciously realized meaning of the situation performs the function of coordinating the particular kinds of regulation (perceptory, mnemonic, and others), the effect of which is to achieve the final goal of activity. Coming into conflict with the inciting motives, the consciously realized meaning-forming motives, which are frequently related to conscious convictions, ultimately determine the qualitative features of the mental state and give it stability and integrity, although the inciting motives, which are sometimes emotionally packed, color the mental states and give them their special emotional hue. Negative experiences which occur while following inciting motives are consciously suppressed.

Thus, in the first place the meaning is represented in the form of a "sensory experience of motives." This is a form of expression of the meaning of the motive itself, and "the meaning of the motives themselves can exist only in a direct emotional form and cannot be verbalized" [6, p 97]. In this case, consciousness of the meaning applies primarily to consciousness of the degree and orientation of the emotional experiences that embody this meaning. In the second place, as a component of the structure of consciousness, personal meaning receives expression in a system of values. In the structure of activities this form of personal meaning expresses the relationship of the motive to the goal and it is ordinarily verbalized.



This representation of personal meaning gives reason to assume that its operational structure under experimental conditions depends on the motive of activity.

In our investigation a series of experiments [5] was carried out according to the K. K. Ioseliani technique. The author's objective was to test the hypothesis of the transformation of personal meaning when the conditions of the activity changed (work by the subjects with and without interference). While working on a special device (modified by engineer A. S. Afanas'yev of the All-Union Scientific Research Institute of Industrial Esthetics), the subject was required to carry on continuous arithmetic operations (addition or subtraction depending on the color of the number), keep the results of the operation in memory, and change it when a new number appeared. The pace of the experiment was set and changed randomly.

Eight subjects took part in the investigation; they were associates at the All-Union Scientific Research Institute of Industrial Esthetics and students of the psychological faculty of Moscow State University. The experiments were conducted on the basis of results of work by the laboratory of functional states of the All-Union Research Institute of Industrial Esthetics. The apparatus and characteristics of performance of assignments were the same as in the first investigation [5]; the change was in the instructions given to the test subjects. They were told to arbitrarily choose a pace of work, aiming primarily to create optimal conditions for error-free work; in other words, the conditions of this investigation formed a motive to choose an "automatic pace." The special character of the instruction caused us not to record the efficiency of the activity in this investigation; this reinforced the motivational difference between this series and the series with work at an externally imposed pace. The test subjects themselves varied the pace in a broader range than had occurred in the first investigation. This was a result of the individual nature of the problem of seeking an "automatic pace" (see Table 1). They worked entirely without interference. The procedure for interrogating the subjects by the "semantic differential" scheme was followed after work at each pace selected.

The coefficient of concordance of the scale given in Table 1 is  $W = 0.26$ ; the same coefficient with inversion of scale 4 was  $W^1 = 0.42$ , giving an actual value of  $X^2 = 17.02$  (with a five-percent level of significance for the table of 18.31).

The primary objective of our experiment was to test the hypothesis of change in the operational structure of personal meaning in relation to a change in the motive of activity caused by instructions where all other conditions remain constant. It is apparent that this change should touch scale 3 of the subjective evaluations, that is the "satisfied-unsatisfied" scale which orients the subjects (according to the instructions of the first experiment) to an evaluation of the goal closely tied to the motive of activity (this supposition was expressed earlier [5]). In other words, scale 3 in the structure

of personal meaning reflects the dynamics of the meaning of the motive of activity under new experimental conditions. Let us recall that in the first study, where the subjects worked without interference, all the scales constituted a single factor when scale 4 was inverted. In this case, preserving the external conditions of the work of the subjects forces us to pay attention to this fact. If scale 4 is inverted, then the coefficient of concordance is 0.42, and when reliability is tested using the  $X^2$  criterion this shows the insignificance of the coefficient obtained at just the five percent level (in the case of an uninverted scale 4 the non-significance of the result increases considerably). This fact illustrates that the structure of personal meaning under conditions of the given experiment has at least two factors. In other words, already in this stage it is possible to state that the structure of personal meaning formed under conditions of the first and second experiments differs, at least in the number of constituent factors.

The next question to be raised concerns the qualitative difference in the factors that describe the particular personal meaning. In this case it is advisable to use factor analysis, a traditional tool for analysis of psychological data [15].

After identifying factor 1 by the centroid method, the necessity of further factoring was tested by Saunders' criterion (the criterion of standard deviation and the Terstoun criterion proved too rigid for determining whether to continue factor identification). The condition for continuation of factoring according to Saunders ( $A > BC$ ) is met in this case ( $A = 0.78$ ;  $B = 0.56$ ;  $C = 0.18$ ).

A similar test of the possibility of further factoring after identification of factor 2 showed that continuation was not advisable ( $A = 0.02$ ;  $B = 0.25$ ;  $C = 0.08$ ).

Thus, in this case the structure of personal meaning is described by two independent factors. After identifying the two centroids, it was found that the structure of them does not fit well with Terstoun's principle of "simple structure," which is adopted in this work. Therefore, the factors were rotated and this produced a structure which corresponded better to the principle adopted. The final factor loads of the scales in each of the factors are shown in Table 2. The level of significance for the correlated vector-scales (0.6 for the modulus) was taken at five percent, and in Table 2 insignificant scales are equal to zero.

Factor 1, which consists of three scales (1, 2, and 4) is the same as the structure of personal meaning formed in the first experiment, that is, it is its verbalized form. Changing the conditions of the experiment by changing the motive of activity, for one, evokes a transformation of the personal meaning that differs from the transformations in the first experiment (differences in conditions while keeping the motive); for two, in this case the personal meaning has a

more complex structure, specifically the direct emotional component of personal meaning acquires independent importance. It appears proper to speak of precisely this form of personal meaning, reflected by factor 2, because the only difference in the conditions of activity during the first and second experiments was the different motivation of this activity while external working conditions, the algorithm of problem solution, and the objective of the work were unchanged.

The presence of a direct emotional form in the structure of personal meaning, and especially the basic role of this component, is something that has been constantly stressed by many authors. Even the personal meaning embodied in a system of values is always clothed in emotional experiences [16]. "The immediate meaning is an essential component of any psychological meaningful formation, either verbalized or non-verbalized; it is its 'basic part'" [6, p 94].

The data presented above show that different levels of transformation of personal meaning are possible. It is experimentally proven that the most profound changes in the structure of this meaning occur as the result of changes in a motive of activity. Where the motive is constant change in the goal structure of activity evokes a transformation of the personal meaning. It is also shown that the principal meaning can be explained by certain methodological procedures, in this case based on an analysis of subjective emotional evaluations. Experimental research results have confirmed the theoretical propositions concerning the structural organization of the psychological content of functional states.

Regarding changing the motive of activity, in the present experiment it was precisely the motive of satisfaction from work that was actualized, even though the instructions suggested identifying the "automatic pace" by the principle of "easiness." This means that the criteria applied for an optimal pace of work do not distinguish the easiness or high reliability of work, but rather an active attitude toward it. This conclusion is further supported by the fact that when asked a second time precisely which pace was optimal the test subject would answer two: the first, slower, pace at which they could work for a long time without errors and a second (a faster pace and the one actually chosen during the experiment) at which they worked with errors, but much more willingly. It can be assumed, therefore, that the phenomenon of satisfaction from work has a complex structure and includes, in addition to a positive emotional frame of mind, an active attitude toward the activity being performed, toward the process and the results.

The possibility in principle of an objective determination of a component of activity such as the personal meaning allows us to determine the algorithm for identifying it, which fits significantly into the problems of standardizing operator activity. Moreover, it is also possible here to optimize the external means of activity,

to plan these means with a predictable effect on the physical and mental strain in operator work because a quantitative evaluation of meaningful formations makes it possible to correlate indexes of different modality in one measurement field.

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## ERGONOMICS

### ERGONOMICS IN DESIGN OF A CONTROLLER'S WORKING ENVIRONMENT

Moscow TEKHNIЧЕСКАЯ ЭСТЕТИКА in Russian No 7, 1978 pp 20-22

[Article by candidate of medical sciences A. M. Achapovskaya, candidate of psychological sciences I. M. Pozet and artist-designer of the Belorussian branch Scientific Research Institute for Styling in Engineering M. I. Sygako: "Ergonomic Premises in Designing the Controller's Working Environment for Operating under Various Conditions"]

[Text] Control work provides uninterrupted monitoring of a control system's condition, makes operational corrections in its functioning and makes possible constant internal improvement of the system. For this reason, such research on problems of its optimization in various respects is very timely: engineering and psychological, physiological, sanitary and hygienic. Many authors (1-9) describe in detail the pattern of controllers' activities, list a comprehensive classification of its component parts and analyze the specific characteristics and difficulties of such work. A special place in the research is assigned to the study of sanitary and hygienic characteristics of the activity of psychophysiological variation developed under its influence in the controller's organism. The results of these studies call, as a whole, for establishing scientifically basic premises for the rational management of a controller's work and of his workplace. But in the literature there are only proposals for the optimization of individual elements of the working process and the workplace since each of the studies covers different aspects of a controller's work. Recommendations in the studies indicated are reduced to requirements whose implementation would lead to the development of uniform conditions of work although the authors also speak of its specific characteristics under various states of the control system. The conclusion may be drawn that identical conditions would be able to ensure the successful implementation of the industrial functions in basically different circumstances under which it is necessary to examine the alternate conditions of a controller produced by significant changes both in the control system and in the controller's organism itself. We suggest that the environment corresponding to the defined working conditions ensures great efficiency of the controller's activity.

We will illustrate this approach to design of the industrial environment with an example of the ergonomic development of conditions for the work of power system controllers.

Integrated ergonomic research on the controllers' activity of various levels of control of the Belorussian power system was carried out in full-scale conditions (the chief control department of Belglavenergo, the central control department of the REU's [Rayon Electric Power Plant] of Mogilevenergo and Vitebskenergo) for a duration of 23 night and day shifts during which emergency and extreme situations in the control systems took place.

Psychological and physiological aspects were studied and the sanitary and hygienic conditions of controllers' work. A detailed time study was conducted; controllers were interviewed and surveyed. (A. A. Bondarenko and M. N. Mamay took part in the research.) In all, 18 controllers from 32 to 49 years of age (two of them women) were investigated. In addition, 44 control worker questionnaires were analyzed from various regions of the country.

The results of the studies indicated that the inflow of information to a controller carries both predetermined (at fixed hours and from specific sources) and nonpredetermined characteristics (associated with unforeseen variations in the control system). On this also depends the psychophysiological stress of the controller observed even under conditions of normal operation. The controller constantly adopts operational solutions according to criteria which, possessing different degrees of significance, are grouped in a well-defined hierarchical sequence. For instance, under conditions of normal operation a continuous supply of users of electrical power is more important to the controller than efficiency. Not infrequently the criteria for adopting solutions are at variance with each other, in conflict even. For this reason, in the process of adopting solutions the controller must, as a rule, either select criteria or seek a compromise. Under conditions of normal functioning of a control system, the controller usually has enough time to perform highly differentiated and extremely critical intellectual activity. He has the chance to turn to the necessary documentation and to get the relevant information from mimic panels and other sources (displays, control and measurement instruments, reference books).

During elimination of malfunctions, the conditions and the nature of the controllers are significantly changed. The number of incoming and outgoing telephone calls grows considerably (according to our data, almost threefold for a comparable period of time). The controller carries out an extensive search for needed information and all possible obstacles and difficulties (breakdown of telephone communications, incorrect calls and so on) disrupt the rhythm of the work, distract the attention and increase nervousness.

Compared with normal operation, any emergency or even extreme state in a control system requires the prompt adoption of a solution. The significance of the criteria for adopting the solution is also changed. Heading the list come such requirements as the reduction of the power supply and the provision of electrical power to users. Because of shortage of time under emergency conditions, a controller does not always have the opportunity to make use of some of the necessary documents and to process adequately all

of the information coming to him. He also finds it difficult to choose the correct solution since at this time signals from different sections of the control system continue to arrive distracting him from the most urgent job--the elimination of the malfunction.

The onset of emergency situations, as our research has indicated, causes pronounced changes in the psychic state of a controller. The posture becomes tense, speech laconic, abrupt and short and movements more goal-directed. Self-control is strengthened (repetition of the signals, notes in draft form and so on). In individual situations an increase in motor activity is observed. A high nervous and emotional tension in the malfunction correction process causes changes in physiological functions. Blood pressure is raised, his asymmetry ratio is increased, rhythm is disrupted and heart contractions become more frequent. The frequency and amplitude of tremors is considerably increased. Even during antiemergency training when the controller is aware of the artificiality of the situation, distinct shifts are observed in the physiological indicators, giving evidence of a highly nervous and emotional stress.

On the night shift a controller has the same responsibilities as on the day shift, but the relationship of the functions is changed. Special assignments come into being which are performed only at night (completing the daily record, compiling data on the daily generating, scheduled switching and removal for repairs and so on). Besides this, the tracking function assumes a special significance on the night shift since the basic characteristics of the state of the control system are exposed at this time to greater changes than during the day. The onset of an emergency on the night shift when the controller alone is carrying the responsibility for the control system is not ruled out. Meanwhile, at night particularly the intensity of psychic and physiological functions (Circadian rhythms) is reduced because of their daily variations (10).

According to the data of current research, the frequency of heart contractions falls about midnight and is returned to the original value only at six o'clock in the morning. Indicators which characterize the heart's state of excitability and conductivity functions vary considerably at night from during the day in all the controllers examined. Blood pressure proved to be lower than during the corresponding hours of the day shift. Of course, the performance of industrial duties by a controller on night shifts is possible only under the condition of maintaining an adequate level of appropriate psychic functioning. It may be assumed that the controller is obliged to control the intellectual functions by will power while for the dynamic nature of other functions, the internal Circadian rhythms are crucial.

Thus, the integrated ergonomic research conducted on controllers' work makes it possible to ascertain its basically different characteristics under conditions of a control system's normal state, during the elimination of emergency situations and at night. On the night shift, a conflict arises between the innate biorhythms developed over a long evolutionary period and



the necessity of existing in a state of courage while maintaining a suitable level of working capacity. Under emergency conditions, the form of the controller's work is drastically changed with increasing nervous and emotional stress. In the first place, the increase in demands made on the controller is in conflict with the deteriorating conditions for their implementation. In the second place, the requirements dictated by the nature of the activity (unusual conflict between biological expedience and social necessity) prevent the natural process of emotional reaction to a dangerous situation. The departure from the biologically expedient means for responding developed in race history or simply its arrest (so-called frustration) adversely affects the controller's health. The excess secretion of catecholamines during intense emotional reactions suggests an increased motor activity (such activity is warranted in natural circumstances); the absence of it causes an accumulation of catecholamine which finally leads to disturbance in the functional state of several systems of the organism (the cardiovascular and the central nervous systems).

Even while controlling a normally operating system, the controller works in conflicting conditions. On the one hand, monotony relaxes the controller, reducing his alertness; on the other hand, there is the need to maintain the readiness and capability to become instantly engaged in action with the arrival of a danger signal.

All of this gives grounds for selecting three different conditions for controllers' activity: 1) control of a normally operating system in the daytime; 2) control of a normally operating system at night; and 3) control of a system during a crisis situation. Combining the last two conditions is possible. The fact of the existence of three fundamentally different conditions for controller activity must be assumed on the basis of its organization in order to increase the efficiency and reliability of labor and to preserve the health of the workers.

Although conditions for controller activity while controlling a normally operating system during the day have been developed, such a problem has not even been raised for the two remaining conditions. By means of industrial design, modifications of the conditions in the controllers' post must be made possible in conformity with the three conditions of activity, varying the parameters of the external environment whose variations serve as a unique dividing line between the conditions and the signal of the start of a new condition. The parameters being varied may be the characteristics of the microclimate, lighting (intensity, color), aural irritants, different effects of which have been adequately well studied in the physiological and psychic functions of man.

It is known that the effect of light on the functional state of an organism and on man's working ability is very great. Light through the pituitary gland and the adrenal cortex produces hormonal action on the autonomic and somatic functions of an organism, stimulating or suppressing them (11). An increase in the intensity of the lighting stimulates the metabolism,

improves activity of the cardiovascular and respiratory systems, produces an overall favorable effect on the psychophysiological functions of a person and on his creative activity (12). Changes in the illumination parameters serve as factors which tone up the state of an organism's functional systems. The research by V. A. Braylovskiy (13) performed at the control post controlling the power stations showed that with lighting variations from 200-350 lux controller working capacity increased by 15 percent.

A significant effect on the psychophysiological functions of a person is produced by the color of the lighting, the photochromatic climate as a whole. According to the data of I. Noyman and P. T. Timpe (11), white light promotes an organism's ergotropic reactions; yellow and reddish lights promote trophotropic reactions.

The effect of the microclimate on an organism is characterized by diverse changes in the physiological functions which influence the level of psychic activity and a person's overall working ability. Thus, the sensation of coolness stimulates intellectual activity, which reaches a high level with temperatures located in the lower ranges of the comfort zone (14). Actually, the metabolism is increased at a temperature of 18-20 degrees since an organism's oxygen consumption intensifies at lower temperatures. Changes in the temperature activate adaptational mechanisms and keep the organism in an active state (5).

Aural irritants have an effect on a person's working ability depending on the nature, rate and time of the exposure to them, the relationship of the person to them and so on (11). Absolute silence is undesirable as is intense noise. Music has a stimulating effect.

Under nocturnal conditions when work is accomplished through will power in a weakened autonomic background, activating agents which have a sympathetic, tonic and overall toning-up effect are advisable. During crisis control situations, it is preferable to create conditions which promote the mobilization of an organism's internal resources. In the first case, such means as washing the face and neck with cold water, coffee, more forceful music, increasing the intensity of the lighting and sources which provide light with a spectral mixture resembling sunlight, dynamic microclimate parameters, physical exercise and the use of biological means for stimulating working capacity (for instance, oxygen treatments) are discussed. In the second case, the complete exclusion of irrelevant external irritants during the accentuated moments plays the leading role in the adoption of an operational solution. Here belong increasing the lighting intensity and lowering the air temperature also. In contrast to the dynamic nature of the parameters proposed for nocturnal conditions, during the elimination of an emergency, it is advisable to maintain stability in the microclimate and lighting. This will promote psychic stability and greater concentration by the controller on carrying out the basic task.

With the factors which limit an emergency situation and which maintain the appropriate psychic tendency should also be grouped the switching on of emergency signals in operating zones, the lighting up of the emergency areas

on a mimic panel, the creation of a preferred channel for communication of emergency messages and the switching over of all incoming requests and communications not having a relationship to the emergency to automatic answering and recording equipment.

Organization of the space in a control room requires special attention. There are grounds for proposing that the zoning of the control room be conducive to managing activity in accordance with the requirements of the conditions described. Thus, separating the operating zone (the panel, equipment for displaying information, etc.) and finding a solution to the problem in a strict practical form without superfluous details and distracting irritants through the use of sources of white light in the daytime and light with the spectral characteristics of sunlight at night should create an effective mood and aid in successful crisis management. Effective psychic relief is possible in a rest area equipped with special accessories for physical exercise and having all of the conditions for complete relaxation (solitude, microclimate, lighting, music and so on). Separating the entrance zone and the eating, sanitary and hygienic zones, besides satisfying the controller's biosocial needs helps to some degree in overcoming monotony. On the one hand, mobility itself and relief from the surrounding situation promote this. On the other hand, being at a distance from the working area sharpens a controller's alertness.

The zoning existing in the control Central Traffic Control Service of the Vitebskenergo REU serves as convincing evidence of the effectiveness of such an approach to solving the problem of optimization of controller activity. It may be assumed that appropriate management of the external surroundings creates conditions for the guided direct and indirect regulation not only of psychic functions (attention, thought, will and so on) but also for the realization of an organism's vital, in depth reactions, which makes it possible to increase the working capacity and efficiency of a controller's work and to preserve his health. Of course, it is not only by the means set forth here that the indicated goal may be achieved. As research has shown, it is also necessary to perform scientifically substantiated occupational sampling and to create conditions for maintaining proper operation throughout a shift and after it.

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## ERGONOMICS

### ERGONOMIC REQUIREMENTS FOR SCIENTIFIC LABOR MANAGEMENT

Moscow TEKHNOCHESKAYA ESTETIKA in Russian No 7, 1978 pp 3-6

[Article by candidate of psychological sciences V. M. Munipov, corresponding member of USSR Academy of Pedagogical Sciences, doctor of psychological sciences, All-Union Scientific Research Institute for Aesthetic Styling in Engineering, V. P. Zinchenko, candidate of economic sciences V. M. Ryss and candidate of medical sciences, Scientific Research Institute for Labor, I. G. Baron: "Ergonomic requirements in Scientific Labor Management"]

[Text] In research on the problems of developing contemporary industry and its control and increasing its efficiency, an ever larger role is being played by combinations of the human sciences. The development of ergonomics reflects social production requirements for synthesis of progress in social economics, natural and technical sciences as applied to the problems of research and design of working processes and conditions. As noted in the recommendations of the Second International Conference of Scientists and Specialists of Sev [Council for Mutual Economic Aid] member countries and the SFRYu [Socialist Federated Republic of Yugoslavia] on Questions of Ergonomics which took place in Bulgaria in 1975, ergonomics is making an increasing contribution to the activity of socialist labor management. This trend has been displayed in a dramatic way in "Intersectorial Requirements and Standards for Scientific Labor Management which must be considered in the Design of New and the Redesign of Functioning Enterprises and the Development of Industrial Processes and Equipment."

The requirements indicated and the standards developed in fulfillment of the resolutions of the 25th CPSU Congress are documents of a general type marking the beginning of a new stage in the development of scientific labor management. This stage is associated with the development of the socialist society being built in our country and creating optimal conditions for the most complete and efficient achievement of the fundamental goals of scientific labor management. Under the conditions of the developing socialism, the problem is emerging in the first plan of the social and economic efficiency of public production. The social consequences of the new technology are becoming conditions for the potential implementation of the economic output invested in them.

A very complete reflection of research in the area of economics, psychology, physiology and industrial design, industrial hygiene and an entire series of technical disciplines as well as top-level experience in the scientific labor management field are found in the approved standards which have come into being as a result of the work of many scientific research organizations and a large authors' union. Here, reflections and primary results of work carried out by Soviet specialists along with specialists of the SEV member countries in a framework of scientific and technical cooperation on the problem of "The Development of Scientific Bases for Economic Standards and Requirements" are found. All of this has become possible mainly because the development of requirements and standards has been accomplished based on unified and progressive aims formulated by the State Committee of the USSR Council of Ministers for Labor and Social Problems. At the base of these goals lies the proposition formulated at the 25th CPSU Congress that the development of mass production based on increasing efficiency and quality is the principle means for achieving the fundamental, long-term goals of economics for developing a socialist society, among which the main goal has been and remains the constant raising of the material and cultural level.

Under the conditions of mature socialism, the problem of the growth of worker prosperity is being solved as an integrated problem, as the creation of all the material and spiritual prerequisites for their comprehensive development. This is the principle aim of the Communist Party and the Soviet Government for the long-term future. In this connection, the standards are permeated with ideas about the fact that the satisfaction of many vital needs of workers (relative to salaries and the attractiveness of work, the improvement of its conditions and so forth) is directly or indirectly related to the actual production in which they are involved. The standards are oriented toward the creation of such equipment and working conditions as would satisfy the cultural and technical level of the workers which is being questioned, make possible the harmonious and comprehensive development of the personality of the human laborer. In developing the standards, they have proceeded from the fact that, in accordance with the basic characteristics of socialist construction, increasing the efficiency of labor may not be done to the detriment of the psychophysiological state and health of a person.

The specific aims of the standards have been established in accordance with the direction expressed by L. I. Brezhnev: "In constructing communism, we should visualize more clearly what the industrial equipment of the future will be like. Of course, without basic scientific research in this area, it is difficult to accomplish anything. Scientists must imagine the technology of tomorrow and work on machines for the future."\*

Analysis of the effect of the separate trends of scientific and technical progress and of the types of new equipment on people, on a person, shows that the circumstances of his life usually result from the conflict of

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\*L. I. Brezhnev, "Pride in Domestic Science," Speech given at the grand meeting in the Kremlin Hall of Congresses dedicated to the 250th Jubilee of the USSR Academy of Sciences, Politizdat, Moscow, 7 Oct 75, p 10.

scientific and technical progress. Although they are a very great benefit to society, scientific and technical progress also have certain negative consequences. With them should be grouped the negative results of the use of equipment and the deterioration of the industrial and natural environment. To prevent the occurrence and development of the negative consequences indicated, the task is being set of developing standards of quality for the industrial and natural environment which should be on a par with technical and economic parameters in the joint value of the consumption cost of new equipment and technology.\* In developing standards for scientific labor management, the problem has been posed that they contribute to the prevention of negative results from equipment use which would cause the industrial and natural environment to deteriorate.

The organic combination of the social, economic and technical aspects of scientific labor management is a bonding principle for standard data. Characteristic for them is a turn to the concrete, qualitative aspects of labor activity of a person (group) which is "one of the most important conditions for changing labor into the primary vital requirement, since it cannot become a requirement of work in general (much less the main one!) without reference to its contents, to that experience, to that range of emotions which it arouses in which the person is involved.\*\*

The specific aims and intersectorial requirements and standards developed on its base are the real answer to the appeal of the Party to strive for organic union of the achievements of the scientific and technical revolution with the advantages of a socialist economic system. The materialization of this appeal is creating conditions also for more complete use of ergonomic and industrial design resources in solving urgent problems of scientific labor management.

Although maintaining a certain continuity, the developed intersectorial standards for scientific labor management are nevertheless considerably different than previous documents of the kind both in the problems, in the scope of coverage of the problems and in the professional level of implementation.

In the standards are found very complete reflections of ergonomic requirements for equipment, the general characteristics of which are included in the article by D. N. Karpukhin and V. G. Gorodetskiy. In the chapter "Ergonomic Requirements for Equipment" the contents of an idea are revealed which are defined by the psychological, physiological, anthropometrical and biomechanical characteristics of man and are assessed with the goal of optimizing his performance.

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\*"Methodological Questions in Determining the Social and Economic Efficiency of New Equipment," Moscow, NAYKA, 1977.

\*\*P. I. Kosolapov, "Socialism. On Questions of Theory," Moscow, MYCL', 1975, p 326.



The ergonomic approach to hygienic standardization is emphasized in the standards and should provide for the creation of optimum conditions for the process of labor activity. According to these factors for which optimum levels have yet to be set, it is necessary in designing equipment to ensure that doses and levels of harmful elements are significantly lower than the acceptable tolerance levels and concentrations.

During equipment designing, calculating the requirements of anthropometrics and biomechanics contained in the standards is aimed toward an optimum working posture, optimum dimensions of working areas and the designed parameters of the work place as well as the one-to-one arrangement of elements which make up the defined working area. For the first time the discrimination of classical and ergonomic anthropometric criteria is being included. Anthropometric data for the male and female population is cited along with dimensions of areas accessible to the motor zone of the work place, by which is understood the expanse of the work place with the arranged controls and other technical equipment in which is carried out the active work of a person in executing a work assignment. Brief characteristics are given for the basic work positions (standing, sitting, lying). Attention is drawn to the fact that, in equipment design and work place management, it is necessary to be guided by the rules of economy of motion since the nature, sequence, paths, rate and rhythm of working motion are determined, in many respects, for the actuating problem, the form and design of the machines and instruments, controls and so on.

In the case of the characteristics of psychophysiological requirements for equipment, an outline description is given of man's psychophysiological organization, which is an integrated system. In it three levels are distinguished.

In the first level are grouped strength, speed, endurance and other physical attributes of the human being as well as characteristics of the nervous system associated with the dynamics of nervous processes and reflex action.

The second is a level considerably more variable with respect to the human attributes during the process of working activity. This level is designated ordinarily as the functional state characterizing the dynamic of man's physiological and psychic functions which are involved in occupational work. Variation of the functional state in the process of work takes place under the influence of physical, psychic or nervous and emotional load and of factors of the industrial environment. Due to variation of the functional state during the process of work being done by a person, changes in his working capacity take place.

The third level of man's psychophysiological structure is the level of psychic processes which has the most dynamic character.

Each level and man's psychophysiological organization as a whole determine the psychophysiological requirements for the equipment and work place organization.

Criteria which make it possible to design optimum and acceptable physical loads with allowance made for the peculiarities of the working process are given for evaluating a work load. Requirements are included in the chapter for information display equipment and controls as well as for their grouping. Characteristics are given of control panels and requirements for workplace technical equipment, workers' seating, workers' platforms, stairs and hatches. The results of ergonomic research are reflected in the requirements for efficient operation and maintenance of equipment. A sample questionnaire is given for analyzing the calculation of ergonomic requirements during equipment design.

The approximate contents of an equipment certificate is given in the standards, in which for the first time ergonomic indicators have been included.

At the current stage in the development of ergonomics and other sciences which study man at work, not all of the pertinent requirements may be taken into account with the necessary thoroughness and concreteness. In particular, requirements of a social and psychological type are not reflected in the standards although they are of primary importance for our industry and for group performance conditions about which K. Marx\* wrote and which are associated with a high level of development of mass production based on public ownership of the tools and means of production. Study and design of concrete forms of labor activity assume the calculation of social and psychological factors which directly affect the nature of the process and results of work.

Calculation of ergonomic requirements is discussed in the intersectorial standards for design solutions and evaluation of the completeness of their implementation at all stages of equipment development. The ergonomic analysis of labor activity is by systems-organized factors in the process of which its description is accomplished and a handbook of occupational principles is composed which includes a definition of the goals and problems of work, of the psychophysiological nature of its conditions, the components and contents which enter into its operation and also the requirements imposed on the technical equipment. This serves as the starting point of the research, the basis for all further work directed toward adapting equipment and working conditions to man.

Calculation of the ergonomic requirements in equipment design includes:

- the provision of optimum distribution of functions in a "man-machine" system;
- the provision of optimum work station organization based on the calculation of anthropometric, biomechanical and psychophysiological requirements in the design of equipment, industrial and management equipment;
- the provision of conformity of technical equipment for labor activity to psychophysiological, biomechanical and anthropometric requirements;
- the provision of optimum values for the industrial environment for the vital activity and working capacity of man through compulsory observance of sanitary and hygienic requirements for the work situations.

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\*K. Marx and F. Engels, "Works," Vol 3, p 75.

Being aware of the fact that special standards and requirements are being developed on the basis of intersectorial requirements and standards, it seems expedient to throw light on some problems which have arisen and found solutions in the process of preparing the intersectorial document.

In developing the ergonomic section, it was intended that the basic results of research be shown as applied to the problem of scientific labor management in order to make them available in a standard form to the large army of designers. In preparing this chapter, the problem was encountered of formulating clearly the basic assumptions and ideas of ergonomics. Controversial aspects were not included in this document; only that which has been approved both in scientific society and in practice has been inserted.

In contrast to previous years, a large amount of practical material has been accumulated at the present time. Ergonomic data which must be used in designing is growing like an avalanche. The problem lies in the task of selecting the most authentic, reliable, comparable data--that which actually must be considered in the process of designing machines for technical processes and enterprises. This selection is being done by large groups of specialists. At times in the past, a complete set of assumptions has been transferred mechanically from foreign manuals which were intended for other purposes and the data for which they were obtained was intended for special groups of people. Here they have been directed above all at results for domestic research.

The next problem encountered by the developers of this section is how to combine the overall simplicity of this document with that complexity which is inevitable in ergonomic requirements. If this problem is allowed to be simplified, then the basic contents of the ergonomic section may be castrated; if it is complicated, then the document will be practically impossible to use widely enough and it will not have the effect for which it was intended. The problem of simplification and complexity has a rather definite reflection in this document. On the one hand, the entire complexity of the calculation of human factors is shown and on the other hand, the maximum possible factual data and recommendations are given for their calculation in order to create through practical workers the necessary conditions for the simplest and most efficient solution of the relevant problem. The problem, specifically, lies in the fact that standardization in ergonomics and scientific labor management is related to man's labor activity. Since human factors are naturally complex and inconsistent phenomena, a particular stereotype and standardization of human activity makes it possible to perform noncreative work efficiently with a minimum of psycho-physiological stress and a maximum of automation. In addition, without the use of a pattern, a stereotype, a standard is impossible and so is a person's creative activity.\*

An important feature of the ergonomic section and of the whole document is that they have been designed both for today and for the future. In fact, these are standards which must be considered while designing new equipment, that equipment which will form the material and technical base of communism.

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\*B. D. Parygin, "Scientific and Technical Revolution and Personality," Moscow, Politizdat, 1978.

For this reason, in preparing the standards the problem has been raised of being oriented toward the optimum values recommended for calculations in the process of designing machines for technology and enterprises. To implement such an approach is not always simple since there are serious scientific reasons for the acceptable values and levels with regard to the optimum values while few of the studies are devoted to their development. Nevertheless, optimum values are contained in the standards for lighting, microclimate and so on and, on the whole, the document has been guided by these values. In preparing the standards, the goal has been set that all of the chapters compose an organic whole, be tied together by a unified idea and have a single core, that is in all of the assumptions of the document, a single line should be followed and advocated. It appears that here as well certain successes have been achieved. The ergonomic section is related organically to the other chapters in which its assumptions are advocated and developed.

The intersectorial requirements and standards for scientific labor management include along with ergonomic requirements the requirements for industrial design and labor safety. Their complex calculation during the design and redesign of enterprises, technological processes and industrial equipment are providing for the reduction of periods for equipment assimilation, increasing of labor efficiency and performance, ease of operation and maintenance, improvement of working conditions, savings on expenditure of physical, nervous and psychic energy of the working man due to the maximum adaption of the equipment to the functional capabilities and peculiarities of man. In the process, a considerable social and economic return is being achieved manifested in the heightening of attractiveness and interest of work, the preservation of health and the maintenance of a high working capacity, the reduction of unproductive expenditures and loss of working time, the lowering of expenditures for exemptions and compensation for work in unfavorable working conditions.

The continual deepening of the connection of ergonomics, industrial design and scientific labor management will permit their development and the more effective participation of the appropriate specialists in the solution of the most important national economic problems. Thus, it makes sense to anticipate the main solution of many problems of the integrated study and optimization of people's labor activities. "New potentials for fruitful research both of a general, fundamental and an applied nature," emphasized L. I. Brezhnev in a report to the 25th CPSU Congress, "are being opened up at the junction of the different sciences, specifically natural and social. They should be put to use in full measure."\*

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\*Materials from the 25th CPSU Congress, Moscow, Politizdat, 1976, p 72.

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## INDUSTRIAL MICROBIOLOGY

### ADMINISTRATION HEAD COMMENTS ON MICROBIOLOGICAL INDUSTRY

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 8 Sep 78 p 2

[Interview with V. Belyayev, Head of the Main Administration of the Microbiological Industry]

[Text] [Question] What are the concrete goals of the microbiological industry in connection with the Resolution of the July Plenum of the CPSU Central Committee?

[Answer] These goals are based on the necessity of organizing mass production in order to supply sufficient amounts of proteins, amino acids, vitamins and other food supplements to the animal husbandry. Also, we have to supply agriculture with bacterial fertilizers and microbiological means of plant protection. This is a relatively young field, but a lot has been accomplished already. The production of nutrient yeast alone for the entire country will exceed one million tons this year. And still we have to admit that we are not keeping up with the increasing demands of agriculture.

The rise of livestock farming does not mean only an increase in cattle stock, but also an increase in the productivity of cattle and poultry. Leonid Il'yich Brezhnev stressed at the July Plenum: "All that we want to have from the animal husbandry is more meat, milk, and other products, and all this, in the final analysis, depends on sufficient supplies of various high-quality feed."

Consequently, this brings about another problem: the problem of nutrient proteins. Because of the lack of proteins in the animal diet, too much food is used. Protein is the most valuable and irreplaceable component of food. The enterprises of the microbiological industry are producing protein industrially by the biosynthesis method. The process is accomplished by growing microorganisms on some raw material: paraffins, methanol, ethanol, natural gas, wastes of the agricultural, wood processing, and pulp and paper industries. As a result of this, nutrient yeast is obtained. It is a protein-vitamin concentrate -- PVC. This concentrate contains up to 60 % of protein, group "B" vitamin complex, and other biologically active substances. With respect to the amount of protein, its amino acid composition, and nutrient value, PVC is superior to the best food of plant origin and is not inferior

to protein supplements of animal origin, such as fish and meat-and-bone meal.

The net profit from the use of one ton of protein-vitamin concentrates is 600-700 rubles in pig farming, and 2000-2500 rubles in poultry farming. Addition of one ton of nutrient yeast to the traditional diet results in additional 800 kilograms of pork and one and a half to two tons of poultry meat, or 25,000-30,000 eggs. PVC is also used for feeding young calves: one ton of nutrient yeast replaces 6-8 tons of natural milk.

What is the secret of this effectiveness? The point is that PVC helps to balance the composition of mixed food with respect to the main component -- protein. The amount of protein-vitamin concentrates produced by the enterprises of the microbiological industry at the present time makes it possible to balance 20 million tons of mixed food. It can be easily understood what national economic effect is produced by using nutrient yeast on a country-wide scale...

The biosynthesis of protein has obvious advantages over other methods of its production, primarily due to the exceptionally high rate of growth of microorganisms. We already have apparatus which can produce 50 tons of the yeast biomass a day. In terms of protein, this amounts to 30 tons. Compare: this amount of protein can be obtained during a season from 40 hectares of soy beans. Moreover, our industry operates all year round: does not depend on the climate, and, therefore, can be organized in any region of the country.

In order to intensify livestock production, it is very important that the food should contain not only sufficient amounts of protein, but also of other components, for example, amino acids. It is particularly important to supply the livestock production industry with indispensable amino acids, which include lysine. Lysine is valuable because, as a rule, there is not enough of it in food of plant origin. We have already been producing lysine by the microbiological method. New capacities will be put into operation during the period of the next five-year plan.

As we can see, various food supplements make it possible to make food rich with respect to all indexes and components, including biologically active substances. Complexes of such substances are called premixes. In the near future, more than one million tons of premixes will be produced, which will make it possible to balance more than 100 million tons of mixed food. We intend to supply premixes not only to the mixed food industry, but also to animal farms of kolkhozes and sovkhozes.

[Question] How effective is the use of biosynthesis products in other branches of agriculture?

[Answer] At the July Plenum of the Central Committee of our party, much attention was given to the expansion of cultivated areas for soy beans and other bean crops. We are also preparing to contribute to this. Nitragin a bacterial fertilizer, will be produced in such a volume that it will be

sufficient for treating millions of hectares of bean crops. It has been shown by farm tests that the introduction of nitrugin into the soil produces from two to seven additional centners of soy beans from each hectare.

Our enterprises are also producing microbiological agents for the protection of plants. What is their value? Such agents act strictly selectively, i.e., against concrete pests and diseases, and do not pollute the environment. They are absolutely harmless for warm-blooded animals and man.

The government allots large amounts of money for solving the above-mentioned problems: the volume of capital investments in our industry will double in comparison with the Tenth Five-Year Plan.

[Question] It is possible to use some microbiological synthesis products in human diet?

[Answer] This is a difficult question... The production and use of protein suitable for human food is the subject of intensive scientific research. However, there arise many technological and psychological problems. What do I have in mind? It is possible to assume that the attitude toward food obtained on the basis of microorganisms will be negative at first. However, it is known that people have been using the "services" of various microorganisms for thousands of years. I have in mind bread making, wine making, beer brewing, and production of cheese and sour milk products. In our opinion, the first food product based on the biomass of microorganisms could be protein obtained from yeast grown on ethyl alcohol. In this case, the "psychological barrier" will be minimal.

The situation with edible mushrooms is much simpler. Research is already in progress on their cultivation and use for food as additives to sausages, sauces, and some varieties of cheese. Food protein will be used either for enriching the ordinary products or independently, in the form of food to which people are accustomed.

[Question] It appears that the development of the microbiological industry is very promising. Could you name the directions of research which are the most interesting from your point of view?

[Answer] Our scientists are developing a technology for growing plant cells. We have already accumulated sufficient experience in cultivating cells of such an exotic plant as ginseng. With respect to its biological activity and such medicinal properties, the extract based on a cultivated biomass is not any inferior than the natural extract. This technology can also be used for growing cells of other rare plants.

A method of obtaining fat from the biomass of yeast has also been developed. Complex processing of such fat makes it possible to obtain fatty acids, biologically active substances, and, which is most important, to replace some of the nutritive vegetable oils which are used now for technical purposes.

I have already mentioned that the microbiological industry is one of the youngest industries of the national economy of the country. There arise many problems in the course of its development. Let us take the construction of new enterprises as an example. Unfortunately, some administrators of construction organizations still underestimate the importance of the construction of new plants of the microbiological industry and their completion on schedule. They consider that this is of secondary importance. The schedule of construction and installation jobs is still not observed at the Angarskiy and Kremenchugskiy PVC plants...

There are also some problems with the supplies of raw materials. The purified liquid petroleum paraffins produced at the enterprises of the Ministry of Petroleum Refining and Petrochemical Industry still do not meet the needs of our industry...

Of course, I could continue to enumerate our problems. Everything new is connected with difficulties, this is natural. But we are looking ahead confidently. The microbiological industry has knowledgeable people full of initiative who are really devoted to their work. We shall do everything necessary to fulfill the Resolutions of the July Plenum of the CPSU Central Committee and the Resolutions of the CPSU Central Committee and USSR Council of Ministers regarding further development of the microbiological industry, to increase the effectiveness of research, experimental, industrial and designing work in order to increase the output of the microbiological synthesis products.

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## INSTRUMENTS AND EQUIPMENT

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### EFFECTS OF LASER RADIATION ON MORPHOLOGY OF PERIPHERAL BLOOD AND BONE MARROW UNDER EXPERIMENTAL AND CLINICAL CONDITIONS

Leningrad VESTNIK KHIRURGII in Russian No 8, 1978 pp 121-126

[Article by Prof G. V. Golovin, Doc I. G. Dutkevich and A. P. Sarkisyan, Chair of Surgical and Therapeutic Hematology and Transfusiology (headed by Prof G. V. Golovin), Laser Group of the Central Scientific Research Laboratory (scientific supervisor: Prof. B. M. Khromov) at the Leningrad Institute for Advanced Training of Physicians imeni S. M. Kirov]

[Text] "Application No. One for lasers is their use in biology and medicine" is a statement made by one of the creators of laser beams, Academician A. M. Prokhorov, recipient of the Lenin and Nobel prizes. Indeed, the range of experimental and clinical studies dealing with the effects of laser beams on biological objects is constantly widening.

Studies are in progress of the effects of laser radiation on the cell and its structures, various tissues, organs and the animal and human organism as a whole [2, 3, 4, 5, 7, 8, 11, 23, 24, 29, 31, 35, 38].

Laser radiation has taken a firm place in the therapeutic armamentarium of ophthalmology, oncology and dermatology; it is being used more and more in the treatment of surgical, internal, gynecological diseases, stomatology, etc. These matters have been covered rather thoroughly in surveys of experimental research and clinical observations in the Soviet and foreign literature [3, 8, 11, 14, 18, 23, 34, 39].

But we failed to encounter in the literature a generalization of the results of experimental and clinical studies of changes in the blood system after exposure of the organism to laser radiation. Peripheral blood and bone marrow can reflect the most sensitively the changes that develop under the influence of laser beams. As yet, few studies have been pursued in this direction and the obtained data are often contradictory, so that definitive conclusions cannot be derived as to the existence of a specific reaction of the hemopoietic system to laser radiation. The urgency of this matter is related to the increasing use of laser beams in science and technology, as well as significant increase in number of individuals servicing them and

use of lasers in clinical practice, with the need to take into consideration potential reactions referable to hemopoietic organs.

Experimental research on this problem began with the study of the effects of lasers on blood cells. They were the first biological object used for the study of the results of laser radiation. Experiments were conducted with a microbeam focused on the cell [4, 28, 30, 32] or irradiation of blood smears [33, 37]. Ruby, neodymium, argon, ultraviolet and helium-neon laser beams were used.

It was established that primarily erythrocytes are destroyed, with retention of white blood cells, but the latter are also destroyed with addition of dye, due to tropism of laser radiation for pigmented elements.

Thus, with the use of a ruby laser with output energy of 0.16 J. there is selective destruction of erythrocytes in blood smears [33]. The erythrocytes swelled, vesicles developed on them and occasionally there was total evaporation. There was little change in the leukocytes. The authors obtained hemolysis of erythrocytes exposed individually to a focused ruby laser beam up to 2-2.5  $\mu\text{m}$  in diameter [30]. Leukocytes were destroyed only after being submitted to vital staining. Human and alligator erythrocytes, leukocytes and thrombocytes were exposed to a focused ruby laser beam [31]. With increase in energy the erythrocytes were destroyed and shriveled into irregularly shaped cells. Leukocytes showed no morphological changes at such levels of energy, but then their ameboid propulsion stopped with preservation of apparent structural integrity. Thereafter, they underwent complete or partial fragmentation, which depended not only on the energy level, but addition of dye. Irradiation of thrombocytes also failed to elicit visible effects until methylene blue was added.

Significant destruction of erythrocytes, limited to the diameter of the beam, probably due to coagulation, was induced by exposing freshly prepared, unstained human and laboratory animal blood smears to ruby lasers (0.5 ms pulses, beam diameter from 250 to 2  $\mu\text{m}$ ) [4]. A focused microbeam induced a hole defect in the erythrocyte corresponding to the diameter of the beam. The leukocytes remained intact in unstained preparations.

In addition to the selectivity of laser beam effects on stained objects, it was found that the severity of lesion also depended on intensity and density of energy, wavelength, pulse duration and other energy characteristics of the luminous flux. For example, hemoglobin absorbs green radiation (wavelength 5300  $\text{\AA}$ ) of neodymium lasers more actively than the red light of ruby lasers (wavelength 6943  $\text{\AA}$ ) [37]. Erythrocytes are highly sensitive to green light [32]. A microbeam of green light from an argon laser was guided through the ocular and objective of a phase-contrast microscope. At wavelengths of 5145 and 4880  $\text{\AA}$ , the beam induced pinpoint coagulation on the surface of the erythrocyte. At 3 mW energy of radiation, the erythrocyte "exploded" and only empty stroma remained.

In experiments with a microbeam of ultraviolet laser with nitrogen (wavelength 3370 Å, mean intensity 2-4 mW, beam diameter 0.6  $\mu\text{m}$ ), focal lesions were obtained on the surface of human and rat erythrocytes. Erythrocytes were totally destroyed at a higher energy [5].

Studies of the effects of helium-neon, ruby and neodymium lasers on a suspension of human blood erythrocytes also demonstrated the decisive role of dye, dependence of severity of lesion on radiation dose, threshold nature of the effect, etc. [1].

Thus, experiments dealing with the effects of laser beams on blood cells revealed specific morphological changes, to the extent of destruction. The severity thereof depended on the energy characteristics of the flux and condition of the cell proper (primarily staining thereof).

The problem of using laser beams in experimental surgery involves such issues as the study of the effects of laser radiation (in continuous and pulsed modes) on various tissues and organs, development of surgical techniques [2, 13, 14, 22, 23], comparative study of operations performed with a laser beam, electric and surgical scalpels, as a result of which it was found that the "luminous scalpel" had a number of advantages: bloodlessness, sterility, absence of trauma, ablaticity and rapid healing of postoperative wounds [2, 14, 17, 18, 22]. Studies were made of the effects of laser radiation on animals with simulation of surgical pathology--wound and inflammatory processes, burns, fractures, skin autografts, experimental tumors, etc. [36, 40].

However, it is only in very few studies that investigation of the effects of lasers on healthy and pathologically altered animal tissues and organs was associated with analysis of changes referable to peripheral blood, its morphological composition, activity of clotting system, etc. [12, 15].

At the same time, several experimental works demonstrated that laser radiation has a substantial effect on the hemopoietic system. Thus, studies were pursued of the effects of pulsed neodymium laser radiation on peripheral blood and bone marrow of 100 albino rats [13]. The output energy of the laser beams constituted 100-200 and 450-500 J. The density of incident energy constituted 500, 1000, 2000, 3000 and 4000 J/cm<sup>2</sup>. Abdominal skin in the region of the liver was exposed to radiation once. The diameter of the radiation field was 0.2-0.8 cm. The authors observed a tendency toward decrease in number of erythrocytes and hemoglobin of peripheral blood at an energy density of 1000 J/cm<sup>2</sup> and appreciable increase at 4000 J/cm<sup>2</sup>. There was a tendency toward leuko-cytosis and thrombocytosis with both radiation variants. In bone marrow there was some intensification of proliferative processes and increase in juvenile forms of megakaryocytes at an energy density of 4000 J/cm<sup>2</sup>, an increase in number of megakaryocytes and moderate depression of leukoblast elements at 1000 J/cm<sup>2</sup>.

Studies of the effects on the blood system of monochromatic red light (MRL) from helium-neon laser beams in experiments on rats and dogs exposed to

total-body radiation (wavelength 6300-6400 Å, exposure time up to 5 min for 10 days) revealed significant (2-fold) increase in hemoglobin and erythrocytes in the animals' blood, reaching a maximum on the 5th day, with normalization of these parameters by the 19th radiation day [9]. On the first day after the start of radiation, leukocytosis appeared and leukocyte count reverted to the initial level on the 5th day.

Investigation of physicochemical changes in erythrocytes under the influence of MRL also confirmed the existence of substantial effects of low-energy radiations on erythropoietic function of bone marrow [10]. White mice were exposed to MRL at a wavelength of 6300-6400 Å. The volume and osmotic resistance of erythrocytes were studied. There was a significant decrease in volume (digital data in relative units) followed by an increase, which the authors attributed to entry of young erythrocytes into the blood. Resistance increased sharply with low doses and decreased with high ones. The latter was attributed to injury to part of the erythrocytes. Resistance increased after 2 days due to appearance of new erythrocytes. Data obtained from studies of changes in age-related composition of erythrocytes in albino rat blood by the method of acid erythrograms according to Gitel'zon and Terskov [20] also were indicative of an increase in number of young erythrocytes. As early as 1 h after the first session (total-body irradiation delivered by two LG-75 at 0.5 mW/cm<sup>2</sup> for 2 min daily), there was a shift in the erythrograms in the direction of highly resistant cells, with normalization by the 11th day. The presence of many young erythrocytes was also confirmed by the appearance of erythrocytes with high DNA content in peripheral blood of pigeons [7]. They were exposed to MRL at a wavelength of 6400 Å and intensity of 1 mW/cm<sup>2</sup>. Both 2-min and 7-h doses stimulated erythropoiesis in bone marrow.

In order to determine the extent of stimulation of medullary hemopoiesis under the influence of MRL of helium-neon lasers, studies were pursued of the histology of bone marrow, daily production of reticulocytes and time of maturation thereof [8]. Albino rats were exposed to total-body irradiation at an intensity of 1 mW/cm<sup>2</sup> for 2 min twice a day, daily. A few hours after irradiation, against the background of a significant decrease in erythrocyte count, there was an increase in reticulocytes (4 times higher than normal) between the 3d and 7th days. On the 17th day, the reticulocyte count remained 25% above normal. Within 7 days, daily production of reticulocytes doubled, the time of change from reticulocyte to normocyte increased from 8 h, which is normal, to 18.5-19 h on the 7th day; it reverted to normal by the 17th day, i.e., many young reticulocytes of grade 2-3 maturity entered the blood stream. Histological and fluorescence microscopic studies of bone marrow confirmed stimulation of hemopoiesis: there was an increase in number of young erythroid elements, somewhat higher mitotic activity than normal and accumulations of hemolyzed erythrocytes. Activation of proliferation lasted for 7-10 days after the start of exposure to MRL.

There was also activation of proliferation in the spleen. Thus, it was found [21] that the spleen is filled with hemolyzed blood and there is prevalence

of young lymphocytes over mature ones, i.e., intensification of reproduction of young cells of red marrow and spleen occurs concurrently with signs of redistribution of blood (decrease in mature erythrocytes in bone marrow, plethora and hemolysis in the spleen).

But, in some studies of the effects of helium-neon lasers on peripheral blood and bone marrow of laboratory animals, changes within the physiological range were obtained [6].

There are data indicative of the danger of thrombus formation [5]. The region of the medulla and mesencephalon of albino rats was exposed to pulsed neodymium lasers (total intensity of energy  $30 \text{ J/cm}^2$ , energy density per pulse  $10 \text{ J/cm}^2$ ). An increase in number of thrombocytes was observed 5 min and 1 day after irradiation, with increase in their aggregational capacity and in number of aggregated thrombocytes, and depression of anticoagulant function [12, 15].

These results of experimental research illustrate adequately the extent to which the obtained data are contradictory and difficult to compare, due to the differences in radiation methods used, vague formulation thereof by the authors in some cases, insufficient number of animals in experimental groups, etc. At the same time, it is obvious that the hemopoietic system does react, and it is just as obvious that more comprehensive studies of such reactions are required.

In clinical surgery, along with increasing use of pulsed and continuous ("laser scalpel") laser radiation during surgery on the gastrointestinal tract, liver and bile ducts, in cases of acute bleeding ulcers and gastric erosions, in oncological practice, etc. [2, 18, 34], low-energy helium-neon laser radiation is also used quite extensively.

Experimental studies have shown that, under specific irradiation modes, low-energy laser radiation stimulates physiological functions of the organism, improves metabolic processes, has an anti-inflammation and vasodilating effect, stimulates erythropoiesis, glycogen synthesis, tissular regeneration, etc. [8, 25, 26].

Physiological, nonthermal, resonance effects of laser radiation are being used more and more in phototherapy of diseases of the joints, trophic ulcers and nonhealing wounds, in the treatment of fractures, endarteritis obliterans and other diseases [16, 25].\* Treatment was delivered to the lesion focus in accordance with developed methods.

\*For more details refer to surveys by B. M. Khromov in the following journals: KLINICHESKAYA MEDITSINA [Clinical Medicine], No 11, 1974, pp 9-14 and KLINICHESKAYA KHIRURGIYA [Clinical Surgery], No 4, 1977, pp 73-79.

In analyzing the therapeutic effects the authors studied, though not in all cases by far, the changes in morphology of peripheral blood after delivering a course of laser therapy to patients. They were concerned with the number of erythrocytes, reticulocytes, hemoglobin level, leukocyte and thrombocyte count, sedimentation rate, and determined the leukocyte formula before and after laser therapy.

A number of authors reported no deleterious effects and expounded the hypothesis that laser energy has a stimulating effect on the hemopoietic system. For example, blood changes after treatment of patients with dystrophic metabolic polyarthrititis and endarteritis obliterans [16] were interpreted as a stimulating effect. Helium-neon laser beams at a wavelength of 6328 Å were used. Exposure time ranged from a few seconds to a few minutes, with 20 treatments per course and 2 courses of therapy. By the 10th treatment of the first course there was a reliable increase in erythrocytes; hemoglobin fluctuated negligibly in the direction of elevation or decline, and the erythrocyte sedimentation rate decreased by the 20th treatment of the first course. The leukocyte count fluctuated within the permissible range. Evaluation of the blood formula in cases of endarteritis obliterans revealed disappearance of relative lymphopenia at the start of therapy and normalization of lymphocyte count. The submitted data are reliable ( $P < 0.02$ ).

Beneficial changes in peripheral blood were observed during postoperative therapy of false joints, as well as bloodless treatment of slow consolidation [26]. Helium-neon laser beams were used. In addition to a good clinical response (faster healing of wounds, intensification of bone repair processes, etc.), the authors observed normalization of the blood formula and lowering of erythrocyte sedimentation rate.

Several authors observed that the morphological composition of peripheral blood did not undergo appreciable change; all parameters were in the range of permissible norms and radiation did not have a deleterious effect on the hemopoietic system. Such findings were reported, for example, with reference to treatment of endarteritis with helium-neon laser beams [19], in the treatment of wounds [27], etc.

It is difficult to assess the changes in peripheral blood indices due to the use of lasers varying in strength, lack of standard radiation technique (different exposure time, intensity of energy, different number of irradiated fields, treatments, etc.) used for the same disease. All this is warranted, to some extent, by the fact that this new type of therapy is at the stage of clinical trial. Quite often, there were too few patients in the groups studied, no comparable data to a control group are available nor are long-term results of therapy reported. Probably, it is necessary to take into consideration the initial physiological background of the patient (state of his nervous, endocrine, cardiovascular and hemopoietic systems) in order to assess the efficacy of therapy and reactions referable to the hemopoietic system.

It is imperative to pursue deeper, more specialized and specific research of both an experimental and clinical nature to investigate the reactions of the hemopoietic system to laser radiation and to make use of expressly the radiation modes that yield, along with a beneficial clinical response, optimum dynamics of morphological indices of peripheral blood.

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## PSYCHOLOGY

### PSYCHOLOGICAL TESTING OF PILOT CANDIDATES

Moscow VOZDUSHNYY TRANSPORT in Russian 13 Jul 78 p 4

[Article by V. Tartarnikov, candidate of the medical sciences, specialist-psychologist: "High School Graduate Takes an Exam"]

[Text] Every year tens of thousands of applications are received by the civil aviation training facilities. A particularly large number want to become aviators. Of course, the profession of pilot is distinguished and interesting, but it makes special demands as well. It is not enough that a student in flight school should have a high level of general education and excellent health. A future pilot must possess a whole series of specific psychological qualities--boldness, decisiveness, cool-headedness, self-control. He must have a highly developed feeling of comradeship, a sense of responsibility for the task he has been entrusted with. A pilot must have good coordination, be a quick and flexible thinker and have a good memory.

Of course, all these qualities are present in the overwhelming majority of people and they can be developed through special training at flight school. However, this is not always true. There exists a special category of students in whom the psychological qualities listed above do not reach the required level, even after special training. Such students usually drop out of flight school. For this reason, starting with 1978 entrants to flight school must pass not only a medical examination but a professional psychological screening as well.

There exist very many methods of determining professional fitness, and these are different for each profession. In the professional-psychological screening of candidates for flight training, psychological tests are usually used--paper and pencil and with apparatus.

Imagine that you are given a table containing 24 black numbers and 24 red ones. You must as quickly as possible locate and indicate the black numbers in ascending order and the red ones in descending order, alternating black and red numbers. For example, you locate: 1-black and 24-red, 2-black and 23-red etc. This test evaluates the characteristic of switching and allocation of attention. Motor characteristics: coordination,

speed and accuracy of reactions are usually evaluated by tests involving apparatus. For the screening for the state aviation flight schools "High School Graduate-1" will be used. On the control panel of this apparatus there are eight signal lights and eight corresponding keys. The lamps light up automatically at different rates and the student must accurately and as quickly as possible press the corresponding key.

But, what is to be done if the candidate, as a result of the psychological screening, is not admitted to the entrance exam of flight school? Does this mean he is not fit for anything?

Of course not. He is not advised to learn to fly, because his individual characteristics do not fit the stringent demands of the pilot's profession. However, this youth might be an excellent technician, engineer or controller. In civil aviation, there are many professions and they are all useful and necessary.

Indeed if a youth is not a quick, flexible and tactical thinker, his thinking is stable and deep, and these are precisely the characteristics necessary for an aviation engineer. Or, take for example, poor ability to switch attention and narrow attention capacity. This indicates that the attention is concentrated and steadfast, that is, that here is a man capable of concentrating for a long time on the solution of complex problems. And without this quality the successful activity of an aviation designer, inventor or efficiency expert is unthinkable. Or finally suppose that a youth has poor coordination, but possesses all the other psychological characteristics for the profession of pilot. He can not be made into a pilot, but he can become an excellent controller of air traffic.

Thus thanks to the results of psychological research, psychologists help young people correctly choose professions suitable for them. Only when a person is in the right job for him does work go well and bring him happiness.

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## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

POLAND, BULGARIA, USSR STUDY GROUP ON HYPOKINESIA ON THE JOB

Moscow TEKHNIЧЕСКАЯ ЭСТЕТИКА in Russian No 8, 1978 p 21

[Article by K. M. Smirnov, LIOT VTsSPS, and L. I. Koncha, VNIITE:  
"Regular Meeting on Ergonomics at CEMA"]

[Text] On 12-18 February 1978 the first tripartite working meeting on the assignment "Investigation of the Essential Motor Activity of a Human Operator Under Conditions of Hypokinesia and Hypodynamia," part of the program of cooperation among CEMA countries on the problem "Development of the Scientific Foundations of Ergonomic Norms and Requirements," was held at the Institute of Industrial Esthetics in Warsaw. Attending the meeting were specialists from cooperating organizations in the CEMA countries, specifically TsPEKhP [expansion unknown] of Bulgaria, the Polish Institute of Industrial Esthetics, and the Soviet LIOT VTsSPS [Leningrad All-Union Scientific Research Institute of Labor Safety of the AUCCTU] and the All-Union Scientific Research Institute of Industrial Esthetics.

During the meeting the division of ergonomics of the Institute of Industrial Esthetics held a symposium with the title "Methodological Questions of Studying the Human Operator Under Conditions of Hypokinesia." A number of communications were presented at this symposium.

The report by E. Slovikovski of Poland served as an introduction to the problem of hypokinesia. This report dealt with the question of the essential features of the phenomenon of "hypokinesia" and proposed that its unfavorable effect be eliminated primarily in the stage of designing machinery and equipment.

The report by K. Smirnov presented research by a group of associates at the Soviet LIOT. The level of motor activity and indexes of the degree of lack of physical training were studied for groups of people engaged in various types of local physical and operator work and in employees engaged in mental labor. It was found that labor in the modern worker professions is characterized by hypokinesia just as much as the "sedentary" mental labor. Observations during the working day

reveal that the low level of general motor activity and local concentration of muscular efforts, the immobility of the working posture, and the uniformity of labor actions reduce the level of alertness of working people; in other words, they bring about a change in the functional state of the nervous system that reduces labor efficiency. In this respect similar or even identical changes in the state of a person influenced by hypokinesia and influenced by monotony of labor deserve special attention. Consideration of this similarity is important to take a number of steps to prevent and correct the unfavorable effect of hypokinesia.

In the reports by D. Senk and K. Lapaciewska of Poland and K. Kyncheva of Bulgaria interesting data was presented on changes in the state of a person given a model labor load under conditions of hypokinesia. These data were obtained on a basis of a uniform methodology. The test subjects worked eight hours a day, performing monotonous actions similar to the work of installing certain small parts, mounting metal washers on pins. The same activity was carried on with four different variations of organization of the work position. These involved getting the washers. In the first case only the wrists and fingers needed to be moved, whereas the other three included additional movements of the elbow joint, shoulder joint, and finally the trunk of the body. A number of physiological and psychophysiological parameters were studied and from their values an attempt was made to identify the optimal degrees of involvement of the skeletal muscles in activity. These studies will be continued, but with results now available it is already possible to describe the degree of localism of muscular efforts as a factor which fosters inadequate motor activity, hypokinesia, and its unfavorable effect on both the state of the working person and on the efficiency of that person's labor.

The report by A. Seber of East Germany reviewed the interrelationships and connections between the ability of a person to execute different forms of model mental labor on the one hand and the individual characteristics of his nervous system and psyche on the other. The data obtained are interesting for selecting people more or less suitable for various occupations and also for organizing labor training for them.

After exchanging opinions the participants in the symposium reached the conclusion that the content of the investigations can provide a general methodological foundation for the upcoming stage of work on the assignment.

The next point on the agenda was communications by the three parties on research performed. It was observed that the Parties are carrying on research in conformity with the working plans. The research results were discussed and, on this basis, forms of introducing them were reviewed and the working program and working plan for the assignment were refined. The task of defining the criteria and parameters of hypokinesia was added to the section of the program entitled "Goals and Tasks of the Investigation." A passage saying that development

materials will provide a foundation for ergonomic recommendations to prevent hypokinesia and lessen its unfavorable effects was added to the section entitled "Expected Results." Drawing up methodological recommendations for determining the degree of and preventing unfavorable consequences of hypokinesia in labor was chosen as the way to conclude work on the assignment and introduce research results into production practice.

The Parties decided to alter the title of the assignment to read "Investigation of the Essential Motor Activity of a Human Operator Under Conditions of Hypokinesia."

A number of organizational matters were also dealt with at the meeting to improve cooperation on this topic.

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## PUBLICATIONS

### NEW CZECH BOOK ON ANALYSIS OF OPERATOR ACTIVITY REVIEWED

Moscow TEKHNICHESKAYA ESTETIKA in Russian No 8, 1978 pp 25-26

[Review by V. B. Lidova and L. B. Mostovaya, All-Union Scientific-Technical Institute of Industrial Esthetics, of the book "Metody rozburu i hodnoceni systemu clovek-stroj" (Methods of Analyzing and Evaluating Human-Machine Systems) by O. Matousek and Z. Zastavka, Czechoslovakian Publishing House of Scientific Literature, Prague, 1977, 176 pages]

[Text] In 1977 the Czechoslovakian Publishing House of Technical Literature published the book "Methods of Analyzing and Evaluating Human-Machine Systems." In the preface to the book the authors O. Matousek and Z. Zastavka, noting the timeliness of the problem of raising labor productivity by taking advantage of the opportunities of scientific-technical progress, emphasize that scientific organization of socialist production is impossible without extensive use of the latest scientific findings on labor activity. The interrelations among the human being, means of labor, and the production environment are the subjects of the study of ergonomics, which views the human being not only as an inalienable constituent part of any planned system but also as the dominant component of the human-machine system.

The book has six chapters.

The first chapter gives a brief historical sketch of the development of the science of labor and traces growth in the role of differential and experimental psychology in forming the comprehensive approach to study of the human being. The authors consider psychology, physiology, labor hygiene, and industrial anthropology to be the most important sciences dealing with labor. An attempt is made to achieve a fundamentally new interdisciplinary approach to solving the problems. This makes paramount the need for a new methodological foundation that uses the findings of general systems theory.

Substantial attention in the chapter is devoted to the present state of ergonomics in the capitalist and socialist countries, above all



Czechoslovakia and the USSR. The main works and leading scientific centers are named and the importance of the International Labor Organization and the World Health Organization is specially emphasized. The role played by the All-Union Scientific Research of Industrial Esthetics in the development of ergonomics and coordination of ergonomic research in the CEMA countries is singled out as well.

The subject and basic problems of ergonomics are analyzed in the second chapter. The subject of ergonomics is defined as the human being-means of production-production environment system in all the inter-relationships among its components. Ergonomics is involved in solving two basic problems: raising labor efficiency and protecting human life and health.

It is observed that the systems approach to problem solving is becoming increasingly important in the development of ergonomics. This is related to the growing complexity of the objects of research, systems in which a significant number of primary and auxiliary components interact simultaneously. Using the systems approach in both the methodological aspect and when solving concrete production problems is, according to the authors' thinking, based on the following principles: consideration of all dynamic relationships among constituent parts of the system; consideration of the productivity of the system as the chief criterion for its evaluation; use of ergonomic criteria in the stage of system design; defining the problems of the human being in the human being-machine system on the basis of the unity and interrelatedness of the person's sensory, mental, physical, and motor capabilities.

In reviewing the components of the human being-machine system (HMS) the directing role of the human being is emphasized and types of HMS's are cited using different classification features (by method of interaction with other systems and the environment; by the nature of relationships among subsystems of the HMS; by the nature and number of the system components).

The authors point out that the capabilities of the human being as a component of the HMS cannot be expressed in an absolute quantity because they are described by a set of somatic, biochemical, physical, and behavioral variables and, furthermore, differ among individuals. When determining a person's capabilities due regard must be given to the professional, emotional, personality, and social factors as applied to the nature of the labor activity.

In their analysis of the concepts of "requirement," "criterion," "index," and "parameter" as used in ergonomics, the authors point to the need for precise definitions of them for practical application of ergonomic findings. Instead of the concept of "ergonomic" requirements in the sense that it is used in State All-Union Standards in the USSR, the authors propose the concept "ergonomic criteria." They separate compound ergonomic criteria into particular criteria:

anthropological, hygienic, psychophysiological, and others, while stipulating that the lines between them cannot be absolutely precise.

In evaluating specific articles they are considered relative to a certain "ideal" norm or compared on the basis of definite criteria. The authors assume it is possible to use the concept of "parameter," which they describe as a quantitative magnitude of a particular ergonomic criterion, to determine the "ideal" norm.

The quantitative expression of ergonomic criteria, in other words, the determination of ergonomic parameters, is possible only for factors such as the dimensions of a human body, magnitude of efforts, and the thresholds for various analyzers. Things are much more complex with psychological factors. Moreover, the difficulties with determining the set of ergonomic criteria are aggravated by individual differences typical of specific functions (sharpness of vision and hearing, physical strength, and the like) and by the effect of the factors of age, state of health, and tolerance. Solving the problem of a model of the human being by which ergonomic criteria and ergonomically sound parameters corresponding to them can be determined is a crucial problem for the further development of ergonomics.

The authors consider the importance of ergonomic parameters in designing HMS's using the example of the evolution of methods of designing machines which led to the application of systems principles.

The third chapter is devoted to methods of analyzing and describing HMS's. In it the authors emphasize that the HMS in ergonomic research should be described and analyzed as a composite unit. By a description of the system the authors mean a list of all its technical and human components without consideration of their interaction. But at the same time analysis of the system assumes that we know the properties and behavior of the components and, therefore, it is possible to define their interaction.

The choice of methods of describing and analyzing HMS's is determined by the principles of objectivity, validity, and reliability, the possibilities of quantitative evaluation, and economic factors. The technique chosen should correspond to the level of analysis and goal of the investigation. Level of analysis means analysis of the system as a whole or analysis of its individual components. The system as a whole is studied with the help of economic methods, analysis of production charts and critical path schedules, and modeling the system by abstract means. The technical component of the system is investigated by means of mathematical and statistical methods and study of technology. The human factor was taken into account by means of an automatic description of labor activity, occupational descriptions, psychological, psychophysiological, and cybernetic methods, anthropometry, and occupational selection and production training.

This chapter also analyzes methodological approaches to learning the reliability of HMS's, which is defined as timely and error-free performance of the task. The problem of human reliability in technical systems can be solved in various ways. One of them is to compare the requirements made by monitoring and control of the concrete system with the physical and psychophysiological capabilities of the human being. Another method assumes study of "critical events," that is, control actions and types of human behavior which can result in deviation of a functioning system from set parameters. It is also possible to study the individual reactions of a person in extreme situations. In light of the solution to the problem under consideration the authors analyze three basic lines of study: biomedical, human factors engineering, and typological, which are being developed in the USSR in research on the working reliability of operators.

Here the book gives a detailed review of methods of direct and indirect determination of the physical and psychophysiological loads.

In the last section of the third chapter the possibility of modeling HMS's by abstract technical means and using the method of two-sided observations are reviewed. The authors stress the advantage of modeling with abstract means.

In chapter four, which was devoted to the development of algorithms for activity in the HMS, one of the principal challenges set down by the authors is met: developing algorithms for those types of activity for whose description and analysis conventional language is not sufficiently accurate. When introducing the concepts of "algorithm," the authors analyze two possible definitions of it, the precise one and the intuitive one. During the subsequent discussion of the problem they prefer work with the intuitive definition of an algorithm, giving the basic properties of the algorithm and methods of writing it, in particular using flow charts. The authors are mainly interested in flow charts of complex types of operator activity that are most typical of HMS's. In this connection two basic groups of typical operator functions are identified. The first group includes observation of discrete means of information representation or groups of them concentrated on instrument panels and receiving various orders and recommendations (oral and written). The second group includes manipulating control elements and other executive operations (making records, issuing orders, and the like).

For complex types of operator activity a graphic form of writing flow charts is introduced and methods of designating their various elements are defined: decision blocks and operation blocks, "START" and "STOP" blocks, and terminal operations, which is to say, operations with which the algorithmized activity can be stopped in emergency situations. The main principles of linkage among particular blocks are also given. The authors explain the concept of flow chart branches, introduce the concept of the open, interrupted, and closed cycle and loop, and

review possible methods of formal and abbreviated nongraphic writing of flow charts. The graphics of flow charts are represented by a set of related geometric figures that correspond to different blocks and are connected by straight lines, which makes it possible to describe, identify, and classify the individual flow charts of the algorithmized labor activity.

The specific methods of distinguishing flow charts and their elements make possible theoretical and empirical evaluations of the flow charts. The theoretical evaluation of flow charts includes the proposition of the equal probability of appearance of flow chart branches, but in reality this is not the case. If the system is working in a normal technological regime it usually has those branches appropriate to it. It is necessary to know a number of empirical values (for example, the frequency and number of flow chart branches realized) to objectively analyze flow charts as algorithms of concrete types of activity.

The fifth chapter is devoted to a classification and evaluation of types of operator activity depending on the prevalence of particular mental functions (attention, perception, and the like), steps to activate them, and also characteristics of determining the causes of deviation of the system from assigned parameters and bringing it into a state of equilibrium. The degree of complexity of operator activity depends on the complexity of the functional ties among the quantities monitored and controlled. It may be expressed by an algorithm whose complexity is then determined by the number of blocks, types of branches, and the like. In many cases deviations are eliminated by using several algorithms leading to the same goal. Choice of the particular algorithm is linked to subjective factors, stereotypes developed by the operator in the process of labor. Individual systems may have many variations of states, and as a result non-traditional decisions for which there is no known algorithm will be required in exceptional circumstances. In such cases the activity of the operator becomes heuristic.

The interaction of elements of the HMS is analyzed in order to classify the types of operator activity. The elements are the subject (human being or group of people), the object (objects of the physical world), and the means (tools, machinery, and equipment). The types of interrelationships among elements of the HMS are presented in a special table. All of the combinations given can be reduced to two groups: 1) non-operator types of production activity (that is, manual labor, work with tools, and operating mechanisms with working parts) that require mastery of fairly complex motor skills but have relatively simple algorithms of activity; 2) operator types of productive activity in which the working movements are fairly simple, but specialized knowledge is very important, in particular knowledge of complex algorithms.

In operator activity the absence of any direct connection between the subject and the object becomes very important; information on the state

of the object of labor is reflected by special equipment. In the opinion of the authors, at the highest level of operator activity the subject lacks not only direct contact with the object of labor but in general with any direct source of information about the object. In this case the information system is replaced by an adjustable mnemonic scheme which processes information about the object and becomes a fundamentally new element of the whole system.

This analysis enables the authors to single out the following key classification characteristics of operator activity: 1) number and types of elements of control and means of information representation, frequency of their use, and characteristics of the linkage between them; 2) operator function in the HMS depending on the degree of automation; 3) degree of worker risk or threat to the operator's health.

Operator activity is subdivided into five types on the basis of these characteristics. The properties and characteristics of elements of flow charts and the structure of graphic algorithms are taken as the foundation in the chart of criteria for classification and psychophysiological evaluation of operator activity based on the principles of development of algorithms.

The final, sixth chapter describes the authors' experience in writing and using flow charts under production conditions. The main thing required to write flow charts is that the investigator be familiar with the technological process and develop a list of relatively independent technical means that make up the entire technical side of the system. Then comes the stage of dividing the activity of the operator into groups of operations: preparation, launching, operation, stopping, and writing the first variation of the flow chart. In the next stage the problem is to investigate and describe the operator's work position and diagram the arrangement of all its elements. Then it is possible to begin writing detailed flow charts within the limits of a group of operations.

The graphic quality of the flow chart makes it possible to use it to optimize the placement of information display equipment and control elements at the operator's work position to streamline labor processes. With theoretical and empirical evaluations it is possible to determine the optimal type of algorithm, corresponding to the most efficient sequence of operations. Individual algorithms, which it is important to write to analyze the activity of several operators, may be recorded in the form of flow charts derived empirically.

In addition, flow charts may be used in the process of operator production training. In control systems where there is heightened risk flow charts make it possible to model emergency situations and define ways to eliminate them. The principles set forth in the chapter are given concrete form in three appendices.

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