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A Novel Methodology Analyzing the Influence of Micro-Stresses on Human-Centric Environments

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Abstract: This article offers experimental studies and a new methodology for analyzing the influence of micro-stresses on human operator activity in man–machine information and search interfaces. Human-centered design is a problem-solving technique that puts real people at the center of the design process. Therefore, mindfulness is one of the most important aspects in various fields such as medicine, industry, and decision-making. The human-operator activity model can be used to create a database of specialized test images and a computer for its implementation. The peculiarity of the tests is that they represent images of real work situations obtained as a result of texture stylization and allow the use of an appropriate search difficulty scale. A mathematical model of a person who makes a decision is built. The requirements for creating a switch to solve the given problem are discussed. This work summarizes the accumulated experience of such studies.

Keywords: human–machine interaction; mathematical model; operator personnel; micro-stresses; test images

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1. Introduction

One of the threats to human health is stress. The problem of stress is highly different in the manifestation of the causes of its occurrence, but the results, in any case, are very undesirable. Intense pressures destroy the body sharply, and weak stresses destroy it slowly, which is mainly manifested in discomfort and a lack of an appropriate reaction. Scientists from many countries are studying the nature of stress, its features, and the consequences of its impact. A general feature of the study of stress is that the study of its causes and their understanding take place after a person has gone through a stressful state when only its consequences can be studied. Doctors and psychologists receive information about such cases much later than the case itself.

Human activity in information and search systems, for example, searching for an object of a given class in the image of a working situation, a specific number in a table, an indicator of a mnemonic, etc., creates information micro-stresses given the high responsibility resting on the decision made. Such micro-stresses are characteristic of almost every person who feels that he has not fulfilled a responsible task, especially when there is a shortage of time.

The peculiarity of the research on the impact of micro-stresses is that an experimental scenario is developed that simulates the activity of a human operator in this information and search system. Its essence is that the operator is provided with a sequence of special images on the monitor screen that simulate real work situations. Such images are created so that the search for an object of a given class requires little effort in terms of the concentration of the visual analyzer of the human operator. However, to simulate a stressful situation in the sequence of such images in cases of rare events, randomly including several images for object detection requires significant brain effort. According to such test images, object detection can be considered a minor micro-stress. Given their exposure time, such a sequence of test images should be relatively large.

The purpose of this study is to develop an experimental research methodology focused on operator personnel in terms of stress resistance and provide recommendations for its consideration in the selection, training, and certification systems of relevant specialists.

The search for analogs among the literary sources was carried out in the following areas: the concept of stress, its detection, and research on micro-stresses; the simulation of human operator activity; the development of models of real work situations; and the organization of computer simulators.

In [1], a systematic approach to stress is presented, integrating knowledge about the nature of stress obtained from the psychology, physiology, and medicine fields. Available information is given in [2] regarding the professional requirements of operators of unmanned aircraft systems and their psycho-physiological qualities, which enable the control of these systems in everyday and extreme situations. The monograph [3] presents the materials for the experimental and theoretical study of information stress in a human operator, which is a psychological form of professional stress. In the monograph [4], modern methods and means for determining and diagnosing emotional stress are considered, and methods and examples of applying the described mathematical models for determining the level of emotional stress are given. In [5], the conditions of the organization of operator workplaces, psychological requirements for information display devices, and management bodies are considered. It is shown in [6] that intellectual stress is present in addition to informational stress, along with emotional signs of stress. The materials provided in [7] reveal different approaches to stress, including its causes, forms, and dynamics, and the authors conduct an assessment that contributes to acquiring and deepening psychological knowledge about stress and its management. As stated in [8], information stress causes mental tension, anxiety, fear, and other psychological states.

Particular attention was paid in [9] to the ergonomic design issues of information models of technological processes. A description of the software that implements the considered methods and models is given. Questions related to constructing a computer model of the formation of information stress and the prediction of the reliability of the activities of operators in different functional states are discussed in [10]. In the article [11], experimental studies of the decision-making processes by a human operator in an intelligent control system are considered, and the results of computer modeling and experiments with operators are given. The work in [12] presents a mathematical model of a human operator of a technological process from the point of view of mathematical systems theory, which takes into account the influence of the human factor on the quality of process management in terms of stress resistance. The work in [13] presents a methodical apparatus for assessing professional stress.

In [14], an analysis of the existing systems and research methods on the human condition was carried out using the Luscher, Zung, and Spielberg tests, the Hamilton scale, and the Holmes and Ray method from the point of view of their effectiveness and informativeness. The work in [15] concerns the identification of a mathematical model of a person and the methodology for measuring mental stress. The authors of [16] propose an approach for image description by segmenting it into regions and indexing them according to given types in the descriptor space. In [17], a formalized test model is proposed that allows vector interpretation, and the possibility of generating tests with a required level of detail and generalization of professional knowledge and their assessment levels is shown. The article [18] is devoted to analyzing modern psychological studies of crises and approaches to their diagnosis, and attention is paid to the typology of stressful situations.

The requirements for computer simulators and the principles of their construction are considered in [19], the role of interactive simulators for personnel training is also shown, and the stages of creating educational electronic products, which include computer simulators, are defined. The article [20] compares the results of an analysis of the development of man–machine systems and previous and current evaluations to identify trends in this development to decide on the next steps. Based on an analysis of the professional activity of a technological process operator in [21], a model of the formation of operator skills in computer training is built. The article [22] presents some aspects of using computer simulations and simulators for training drivers and crews and possible options for their application.

In [23], the authors identified three types of micro-stresses, which include the following: stresses that reduce our personal efficiency, stresses that reduce our emotional reserves, and stressors that challenge our identity or values. The requirements for psychological testing are given in [24].

The analysis of already existing scientific works showed that not all works can be used in practice to give a good result. After all, the works are mainly focused on one type of mental problem [25] or have a strong dependence on the location of a person, his age, or a certain situation in a given location (for example, a pandemic) [26].

In some works and solutions, the results did not have very high accuracy (about 71%) [27], which is not enough for either health or medicine. Also, the existing systems are quite complex and require a lot of resources because they have many stages of data preprocessing, several algorithms are applied sequentially, and many restrictions are imposed on the input data or datasets for training [28]. Therefore, taking into account all the above nuances, the results of forecasts may not be accurate in many cases, which is unacceptable when forecasting diseases. That is why there is a need to find a solution that is generalized and does not depend on factors such as age, gender, place of residence, etc., and that will also support the prediction of at least the most common psychological and mental disorders.

In the studies [29,30], a dual technique combined with the Laplace residual power series method and a new iteration method is proposed. The approximate and effective solutions to the foam drainage equation and the nonlinear time-fractional Fisher's equation bring fresh insights into the behavior of these complicated mathematical models as a result of these studies.

Papers [31,32] used modern machine learning techniques and mathematical modeling for time series analysis taking into account the semantics of collected data.

Therefore, this paper aims to develop a complex methodology for analyzing the influence of micro-stresses on human-operator activity in information-searching human–machine interfaces. To do that, image processing will be used.

The contributions of this paper are given as follows:

- The mathematical model of the human–machine interface in search engines for the implementation of a reaction to the detected object is proposed. This model is presented as a dynamic system that allows the simulation of the next state of the operator personnel.
- A computer simulator and test image generator are developed. They allow for the evaluation of stress resistance based on a micro-stress and mindfulness comparison. A sequence of images at discrete moments is generated. On the monitor screen, the operator is exposed to a sequence of test images with objects of attention of a given class, and the operator must implement the corresponding solution. The moments of their exposure and the decisions made by the operator are recorded, and their values are included in the research protocol.

2. Materials and Methods

2.1. Stress and Micro-Stresses in Operator Activity

Stress is often understood as a condition with severe nervous tension. As a rule, in operator activity, a person in such a state does not begin to perform his functions, but such a state can also arise directly in the process of an activity itself. In the general view of stress, it is believed that it is the body's reaction to a strong feeling caused by one or another stimulus. For many cases of stress, there are adaptive mechanisms that reduce significant stress. Stress researchers distinguish the following successive stages of its course:

- Anxiety reaction. The action of the stressor triggers the fight response, which activates the sympathetic nervous system, which mobilizes functional reserves to fight against stress. Typical physiological manifestations are a rapid heartbeat and breathing,

dilated pupils, and trembling hands. As a result, the operator may have difficulties with orientation.
- Resistance reaction (adaptation). If it is not immediately possible to deal with stress, blood pressure rises, and the body's resistance to extreme stimuli usually increases. The operator mobilizes the will and desire to overcome the non-standard situation. In non-standard circumstances, his mental and muscular activities are activated. If the action of the stressor at this stage stops or weakens, the changes it causes will gradually normalize.
- Recovery reaction (exhaustion). If the body can counteract stress, its resources have not yet been exhausted and recovery begins. However, being in the phase of exhaustion, a person no longer has the necessary resources; therefore, persistent exhaustion of the entire organism develops, and anxiety appears again. Manifestations of such maladaptation concern emotional, cognitive, and somatic spheres.

Stress is also associated with reduced productivity, a lack of motivation, and poor decision-making. There is no question about the role of stress in causing burnout, withdrawal, and depression.

The term micro-stress sometimes appears in psychological publications dealing with research on stress phenomena. Micro-stress, as it is mainly explained and understood, is a momentary or subconscious reaction of resistance that lasts for a very short time. It is not easy to understand. Each micro-stress can be considered, on the one hand, as a reaction to a stimulus, and on the other, as an action to a response formed at the subconscious level. The onset of stress excitability is called a shock because, at this moment, the mind stops giving specific orders regarding the situation. The end of stressful excitement is calming down. Micro-stress duration from the beginning to the end is concise—from a fraction of a second to several seconds. At this time, a person reacts instantly to what is happening to him personally. Each micro-stress sharply activates and mobilizes consciousness to search for an appropriate reaction. Each person's response to the same stimulus may be different. During the day, micro-stresses accumulate in the form of instant responses to minor stimuli; at the end of the day, they are expressed as significant fatigue.

Stress significantly impacts work productivity, as stressed people tend to make poor decisions and are often less motivated, innovative, and productive. Although often minor, these small stresses can quickly become the norm, making them very difficult to notice. Over time, the level of stress can become very high. In [23], the authors identified three types of micro-strains, which include the following:

1. Stresses that reduce our performance. According to the authors, working capacity is the amount of time and energy a person has to manage himself and all the demands he faces at work and outside of it. Generally speaking, these stresses either create additional work or make existing work more difficult. Increased employment, primary responsibility, and psychological stress also fall into this category.
2. Stresses that reduce our emotional reserves are usually associated with negative feelings such as anxiety, responsibility, and discomfort.
3. Stresses that challenge our identity or values. The last set of stresses is related to our personality problems, which mainly occur in collective types of work and are mostly related to incompatibility.

Thus, although micro-stresses are an integral part of our lives, they significantly impact the results of human activity, especially when making highly responsible operational decisions in complex management systems, which are carried out based on current information received from the monitor screen. One such source of micro-stress in the field of information and search can be a sudden change in information flow due to the lack of immediately required information. The example of operator activity in the human–machine interface of a search engine can explain such a situation. During a work shift, the human operator processes a sequence of images of scenes of the entire work process to identify the necessary objects for making a responsible decision. When the work has been going at an average pace, it is easy to search for and identify the required objects. The operator is in a normal psychophysiological state, feels no discomfort, and is focused on his work. Suddenly, the operator does not see the object he is looking for—he mobilizes his internal resources only to search for this object; he knows that it is there, but where?

Micro-stress analysis is a concept in user experience (UX) design that involves identifying and mitigating small stressors or points of friction that users may encounter while interacting with a product or interface. These micro-stressors can accumulate and lead to a negative overall user experience. Analyzing and addressing these issues can improve the usability and user satisfaction of a design.

Mindfulness can also help designers in the iterative design process. Designers need to be open to feedback and willing to make changes based on what they learn from users. By practicing mindfulness, designers can approach feedback with a non-judgmental and receptive mindset, leading to more effective problem-solving and iteration. The generated test images can also be used in the medical domain for the identification of the stress level.

In summary, the relationship among human-centered design, mindfulness, and micro-stress analysis lies in their collective focus on creating user-friendly and stress-free experiences. Designers who practice mindfulness can better understand and address the subtle issues that users face, ultimately leading to more effective human-centered design and improved user experiences in the context of test images and beyond.

The operator realizes that the exposure time of the image of the scene with the sought-after object is decreasing, and his neuropsychological state becomes overstressed, perhaps close to panic; he imagines (sees) the terrible consequences that can happen if he does not find the object. Such a situation can be created by including objects that are somewhat difficult to detect in the sequence of test images provided to the recipient, which, in principle, should simulate micro-stressful situations. Experimental research should be organized in this way.

2.2. A Mathematical Model of the Human–Machine Interface in Search Engines

The pair "operator-computer" (human–machine) is the most widespread subsystem of almost all automated information and search systems, management systems of technical objects, and technological processes. It is the first link that bears responsibility for the consequences of implementing its decisions. Primarily, the responsibility concerns the human operator, whose reliability is decisive for this subsystem and the entire system. The purpose of such subsystems is highly diverse, but from a functional point of view, they have quite a lot in common.

In the object search subsystem, the operation, denoted by L, can be presented as follows. Suppose a human operator processes several images sequentially displayed on a monitor in some information and search system. During working hours, he looks at the sequence of these images on the monitor to solve a specific task, namely, to identify an object of a given class. The set of images $r_i \in R$, where $R = \{r_i : r_1, r_2, \cdots, r_n\}$ and $i = 1, N$ are integer indices of these images, characterizes specific scenes of an actual work situation. The objects of attention in a certain class identified in these images determine the further development of this situation. The operator is responsible for detecting each object L, knowing that the failure to detect or an untimely detection of such an object leads to negative consequences.

Let L, i.e., a human operator, act on a time interval $[0, T_0]$. The sequence of these images is the only informational source of data for him, as it sets the (x_i, y_i) coordinates of the localization of the objects searched for on these images. In other words, the L operator should detect objects whose localization on the provided images is determined by coordinates $(x_1, y_1), (x_2, y_2) \ldots (x_N, y_N)$. These objects of attention are located on the images randomly. Therefore, their detection has a particular complexity v_i. Quantitatively, the corresponding sequence of indicators of complexity $v_1, v_2 \ldots v_N$ can represent the sequence of images.

In this study, the indicators of complexity play the most significant role. At a low level of complexity, detecting the search object is quite simple—it seems to be in front of the operator, and its image is clear and not masked by other objects or the background texture. However, if the complexity index is high, then the search object may be well-camouflaged and merge with the background or neighboring objects. Therefore, to detect the object, the operator needs to mobilize attention, strain his vision, and, preferably, with high consequences for not detecting the object, he may go into a nervously tense state, which causes different levels of stress.

The exposure time of the provided image on the information field—the monitor, primarily characterized by displaying real situations, i.e., external devices: video cameras, special sensors, or control equipment—can be different. Depending on the means of observation, the moments of exposure of the images of these real situations can be regular when the time of exposure and change in images is the same duration for all images. However, when these durations are random, the presentation of images is irregular.

The localization of the image of the search object, $r_i(x_i, y_i), r_i \in R, i = \overline{1, N}$, which is specified by its coordinates (x_i, y_i), is related to the moment of exposure of the image, $\tau_i, i = \overline{1, N}$, and the $t_0 \leq \tau_1 \leq \tau_2 \leq \ldots \leq \tau_N \leq T_0$ condition is met.

Since the stream of provided images is formed outside the human–machine interface, the L operator cannot change either the sequence of images or the duration of their exposure. An important point in the systems for training and professional selection of candidates for operator activity is the achieved or current level of qualification, which can be formally presented in this way. Let the operator L act on the time interval $[0, T_0]$, and the only information source for him is the given sequence of images. Then, his qualifications, experience, and knowledge can be formally presented in the following way. Let the number $N' \in N$ of viewed and processed images in previous studies and training be determined by the time segments spent on each image $\tau_1 \leq \tau_2 \leq \ldots \leq \tau_{N'} \leq 0$. It is obvious that the sum of the individual time values of these segments, divided by their number, characterizes the recipient's efficiency. The number of images in the flow of the current study is formally presented as follows:

$$0 < \tau_{N'+1} \leq \tau_{N'+2} \leq \ldots \leq \tau_N \leq T_0. \tag{1}$$

Let $D_L(0) = \left\{ ((x_i, y_i), v_i) \middle| i = \overline{1, N'} \right\}$ be all the images of the information flow processed by the operator up to the moment of time $t = 0$. This means that the operator already has specific knowledge and some experience with this activity. We can also consider that $D_L(0)$ is the result of his learning in the sense of knowledge about the information flow. We can also assume that by the time $t = 0$, the operator L has received all the information necessary for work regarding the stream of images about the actual work situation. After training, the operator L must detect a given object localized on the given image in a minimum amount of time.

On the other hand, object detection has a particular difficulty since the localization of objects on the images that make up this sequence is random. This means that in some images, the object of attention is easy to find, while in others, it is tricky.

Therefore, the operator spends the corresponding neuropsychological resource searching for an object, each characterized by a particular difficulty of its detection $C(x_i, y_i) = C_{v_i}(\tau_i)$, $i = \overline{1, N}$. Let us denote this resource by $M_L(t)$, $t \in [0, T_0]$. The greater the problem of detection, the more resources are spent. With the high complexity of the images and their significant number, the operator is about to go into a stressful state, even in the case of one embodiment. In actual work situations, as a rule, this resource can be restored, for example, by a short rest, new additional information, recommendations from the outside, etc., but in highly responsible systems and under unusual conditions, this resource is not restored immediately, that is, it takes a long time.

So, by simulating the difficulty of detecting an object already in models of scenes of real work situations, you can create images with the appropriate level of complexity and, in this way, simulate micro-stressful situations in laboratory conditions. However, it is worth making the following remark: stress is not manifested in time indicators but in psychophysiological indicators. Here, time only indicates the situations in which the transition to a stressful state is most likely.

To establish the relationship between the input and output of the system, which refers to different moments of time, the general mathematical theory of systems introduces the concept of the system's response to an input stimulus. In other words, for each operating situation, that is, for each image on the screen for an operator in a normal functional state, there are two such displays:

- Decision-making:

$$\overline{\rho} = \{\rho_t : C_t \times X_t \to Y_t \ \& \ t \in T\}, \tag{2}$$

- Changing the state:

$$\overline{\varphi} = \left\{\varphi_{tt'} : C_t \times X_{tt'} \to C_{t'} \ \& \ t,\ \ t' \in T \ \& \ t' > t\right\}. \tag{3}$$

These reflections can be explained as follows. While in the state C_t of time $t \in T$, the operator perceives the image $x_t \in X$, detects the desired object on it, analyzes the situation, and makes a decision $y_t \in Y$. The operator normally spends the necessary time on this without changing his functional state (there is no nervousness or mental tension).

If the provided image turns out to be such that it is not possible to immediately find the desired object, and the time limit for the search is limited, the operator can switch from a normal state to a nervous state and continue the search for the object. Assuming that at the moment $t \in T$, the operator has not detected the object and feels that the exposure time is running out, he is aware of the complexity of the situation, and at that moment, he can get a shock. This shock can be interpreted as stress or micro-stress. The double time index means the time interval $t' > t$ during which the operator passed from a normal to a neuropsychic state.

In general, the model of the human–machine interface as an information and search system can be represented by a tuple

$$S = \langle X,\ Y,\ C,\ \rho,\ \varphi,\ T\rangle. \tag{4}$$

Using the mathematical apparatus of theory sets provides an opportunity to optimize the organization of research since sets are presented quantitatively, the mappings of which are considered functionally, and all of them are defined in time. In addition, based on such a model, it is possible to create a sufficient number of images that simulate the scenes of almost any actual camera activity.

2.3. Tests: Concept and Requirements

In experimental studies of the activity of a human operator, the input information is mainly not the original images of real situations but their copies processed in a certain way. Such processing complicates the search for the object of attention: noise is imposed on such an image, other entities mask the sought object, or the vision is blurred or textured in a certain way. In addition, for the quantitative assessment of the recipient's qualification level, data obtained in previous experiments are used, and a corresponding scale of search complexity in time units is established for each image. After such processing, these images are called the generally accepted term: test images. As a result of experimental research using such test images, individual quantitative and qualitative psychological indicators of the recipient are established.

A general requirement for any test is to determine the characteristics of the recipient's behavior under the existing environmental conditions and the assigned tasks. Therefore, it is important to focus tests on specific tasks. The main difficulty in assessing the qualifications of a human operator using specialized test images in the tasks of searching for and identifying objects of a given class is that the same image is processed by different operators with the same level of training at different times. In addition, the operator at different moments also processes the same image at different times.

Their localization is of significant importance when searching for objects in these images. This is mainly the difficulty of their detection and the masking effect of other objects. The main problem in creating test images is determining their complexity, i.e., the relation to them from the operator's point of view. In other words, in such experiments, the result establishes the relationship "complexity of the object-detection time" for each operator. The only indicator of the complexity of an image with an object is the average processing time of this image by a group of expert operators or at least a group of recipients. Therefore, in computer training systems, image tests are used, which indicate complexity. Additional quantitative statistical and geometric characteristics may be known or determined for them, including the parameters of algorithms for their creation.

In the experiments, the test images are organized as sequences of scenes of the real work process for a given exposure duration. In such sequences, the same ideas can be reused, but they differ in the localization of objects on them. Suppose the exposure time is not very short—a few seconds or more. In that case, the recipient highlights and remembers individual elements and fragments of the background. In subsequent images, he will spend time searching for such details, which can significantly reduce the objectivity of the data. Therefore, to divert attention to the background elements of the scene test image, the background image is subjected to textural stylization. Texture stylization refers to segmenting a background image into segments of approximately the same color gamut, with all pixels in each such piece replaced by an average color.

In a certain way, this allows you to avoid unwanted memorization of special fragment elements because, during the search, areas with uniform color are instantly ignored. Texture stylization provides more excellent uniformity of the background of similar original images and, at the same time, blurs small details. Each such test image represents a background characteristic of a simulated work situation; that is, it one of the scenes of the work process.

The image of the desired object is superimposed on the textured image of the background obtained in this way, mostly by randomly varying its position so that it is easy to detect in some cases. In others, it is more complicated. The size of the objects, as a rule, is quite small, mostly within 10×10 pixels of one color, and the background, to exclude the operator from memorizing its fragments, is made texturally stylized, which imitates its blurring, low contrast, and, in general, the uniformity of all images in the set. In addition, due to the rotation of the textured image, the number of options for their presentation increases since the rotated images are quite difficult to distinguish. The essence of turning stylized images allows you to perceive the original and rotate it by 90° or 180° as two different ones, especially when there is a shortage of time. The number of test images, with detected or undetected search objects, about the number of images in this set, serves as estimates of the quality of the work and, therefore, the level of the operator's qualification.

In the process of developing this type of image for conducting professional testing, namely, to characterize the ability to be tested and measure the valid level of a given property or quality (in this case, the efficiency of detecting the object of attention) of the recipient, the concept of validity is used. The validity of the test shows the extent to which it measures the quality (property, ability, characteristic, etc.) that it is intended to assess. There are three main types of validity: content (logical), conceptual, and empirical.

Content validity means validity from the point of view of experts, where the test is valid if an expert thinks so. Content validity should be distinguished from apparent external validity.

Conceptual validity is validity from the point of view of a researcher about the measured indicator. This is the impression about the subject of measurement that was formed when the researcher became acquainted with the instructions and the test material. The testing process primarily determines the researcher's attitude to this measurement.

Empirical validity consists of determining the ability of a test to be an indicator of a strictly defined feature or form of human behavior. To measure this property of the test, the correlation coefficient of the test result with some external criterion is calculated.

Thus, developing tests to assess the quality and efficiency of operator activity is an important and responsible task, and adequately developed tests themselves are specific metrological means. The information obtained from the correct organization and conduct of the testing procedure, with the help of properly designed and prepared tests, provides a high guarantee for an objective assessment of the investigated parameters of information and search system operators.

Such image tests must meet all the requirements of psychological tests since they are related to the work of a person's visual analyzer and functional (psychophysiological) state. A psychological test is a standardized, often time-limited test used to establish quantitative and qualitative psychological characteristics of an individual. The main task of the test is to predict a subject's future behavior.

This imaging test simulates a work situation, focusing the recipient's attention on the input information and leaving out the natural work environment. It is one of the types of psychological tests in which a person is asked to perform a task in a situation that does not correspond to the real situation. Such tests are used in the process of selecting applicants for work, in particular, for the staff of camera personnel. In addition, these image tests are essential for the attestation of personnel regarding their choice of an adequate solution in a given work situation.

3. Results

3.1. Construction of Stylized Images

To create the background of the test images in this study, textural stylization is uses. This is a specific type of distortion of an image, as the test image must be abstract for the testing procedure to exclude the recipient from remembering individual fragments that can be associated with previous scenes and distract his attention from the search process.

In this work, the stylization of the background was investigated by calculating the average value of the color of the pixels in the sliding window and then replacing all the pixels in this window with this color. In other words, this image stylization is based on the sequential averaging of color components in a square window of a given size. The smaller the window size, the less the image differs from the original (original). When the size of the window increases, the clarity of the image elements is lost. As a result, the image becomes abstract and practically devoid of content. Such images are quite difficult to remember, and, as a rule, attention is not focused on them. The main feature of this approach is that with the rotation of such an image from top to bottom and from left to right, one's vision first perceives these options as four different images. However, the structure and characteristics of such a background remain unchanged.

The necessary effect, i.e., the result of stylization, is obtained thanks to the consistent movement of the window in the image plane from left to right and from top to bottom. Such movement can be performed pixel-by-pixel or through one, two, or more pixels. The result of applying this algorithm is shown in Figure 1.

An aircraft over some area obtained the image to be used as a background. It is clear and contains many small colorful fragments. However, as we use different variants of this algorithm, we obtain an imitation of this image that is practically devoid of any logic in its fragments, and the visual analyzer cannot focus on anything; the image is abstract. The tasks of the research should determine the choice of option.

In addition to averaging the color components in the sliding window, the median can be determined. The colors of the window elements are converted into binary and ranked, the median is determined, and the color of the remaining pixels of the window is replaced with the original color of the pixel belonging to the median. Using the median of the color components in the areas of the image leads to a similar effect—the result is a distorted abstract image. Images obtained using the median method with different steps are shown in Figure 2.

Figure 1. Sequential merging of pixels using the method of the average (ascending).

Figure 2. Sequential merging of pixels using the method of median smoothing.

As seen from the algorithm's first pass, the image becomes quite abstract, but some of its content is still present. However, subsequent re-applications produce only random fragments of different colors and shapes in size and shape but of the same texture. The last images of the median transformation can be used as tests only when the images of the objects of attention are quite small, consisting of elements of different color areas close to the background color. They generally approach them but do not merge with them. They must be sufficiently visible and guarantee their detection.

Experimental research of operator search activity involves creating a task in the form of a certain game with appropriate incentives and penalties. Isolated experiments with such images do not give a complete picture of such search activity. Therefore, sets are used for each game. Figure 3 shows a view of such an image with objects of attention of a given class localized on it. In the selected circles, the objects of concentration have the shape of rectangles of a darker color than the background. In this case, it is a class of rectangular objects. They differ in color and size and are marked with circles. One object is in the upper process, and two are in the middle. For example, in the given task, the objects can be cars, tents, etc. The lower circle has a less visible object and its left edge merges with the background. It can be detected and recognized only by geometric features of straight lines and angles. An important point in the localization of objects on the image is the position of the visual axis when shooting. In this image, the terrain is photographed at an angle to the horizon, not perpendicular to the surface. In this case, it is necessary to consider the change in the size of the searched object according to the image's perspective, i.e., the objects located in the distance should have smaller sizes than those localized in the front.

Figure 3. View of search objects on test images. Objects are rectangular. In the upper circle, there is one object; in the middle, there are two objects, and in the lower circle, there is one large object.

In studying the stress resistance of camera personnel, such image tests make it possible to quantitatively evaluate such an individual characteristic of the recipient as the efficiency of search activity. The fact is that working with such images is characteristic of information search systems, which are characterized by a high responsibility for identifying search objects. For example, searching for information sources based on abstracts, detecting defects in materials during ultrasound or X-ray analysis, searching for objects on the surface of land or water, etc. In such tasks, both responsibility and search time can be different. However, under time shortage and high commitment, the difficulty of identifying a given object can become a significant stressor. In training systems, it is almost impossible to simulate real stressors. However, when there are many images on which it is easy to detect objects in the experiment during testing, the operator becomes accustomed to this situation.

He is comfortable and intuitively feels that he will pass the test effortlessly and quickly. If, on the other hand, an image with a well-disguised object appears in the provided sequence of test images, and especially, if the search time is strictly limited, the operator will feel a particular shock, and his expected "victory"—i.e., a high evaluation of his work—may drop sharply. This moment indicates the transition to a stressful state. In laboratory studies, such stresses are not dangerous but can be classified as micro-stresses.

In addition, if the study duration is close to the actual time of the operator's work shift, the number of such situations is several dozen. They occur at random moments. It can be considered that the simulation of micro-stressful conditions and their study is an entirely satisfactory result of the experiment.

3.2. A Computer Simulator as a Means for Stress Research

Today, computer simulators are a widely used educational tool for selecting, training, and certifying operator personnel in various subject areas of human activity. They are specialized and professionally oriented training environments close to the conditions in which the operator works when managing an actual technological process. In addition, they are mainly the technical means by which the development of test images is carried out.

A person and a computer form a system in which the professional activity of a human operator is carried out. In the computer simulator, the operator performs his functions with the help of a remote control (keyboard, joystick, "mouse" manipulator) or voice, receiving information from the monitor screen and other means of information display. The informational and spatial environment reproduced in the simulator should be similar in appearance and function to the same one in natural systems. The essence of this requirement means excluding the transfer of negative skills when the operator transitions to the control of an actual installation. That is, adaptation to the educational work environment is banned.

Creating a computer simulator as a training tool means reproducing the appropriate target function of the man–machine system, specifically intended for operator training. The target function of the computer simulator sets the following requirements:

- To ensure an adequate information model of the management object;
- To ensure qualitative and quantitative analysis of information and decision-making;
- To form and improve the operator's professional skills and abilities.

The human operator's workplace simulator should simulate fundamental functions, external and internal connections, and the working environment with an accuracy sufficient to solve the assigned tasks. In other words, the differences between the simulator and the natural working environment should be within acceptable limits and ensure the adequacy of goals and conditions, interface (operator workplace), information flows, principles of ergonomics, and psychological adaptation. This system of the computer simulator ensures the correct formation of the operator's skills and abilities.

One of the essential elements of computer simulators is the possibility of using the interactive mode, which allows the recipient to fully immerse himself in the work process and consider various events and options for development in the given scenario. In other words, the recipient works with models of real situations as if they were real situations. This, in turn, puts the adequacy of models of real work situations in first place. The interactive training mode consists of three stages:

1. Familiarization with the main elements of the simulator and its use.
2. The training process is developed based on the scenario.
3. The scenario should ensure that the value of the learning indicators is obtained.

Here, we are talking about the recipient's independent work on the simulator. The training mode performs its primary function, which consists of teaching and practicing the necessary professional skills and solving the tasks.

Therefore, using computer simulators provides an opportunity to simulate operator activity by conducting practical classes in light of the necessary competencies and the formation of highly qualified personnel. This type of training—computer training—is very relevant for training highly qualified personnel in managing dynamic objects. The need for such specialists is especially significant when objects are controlled remotely.

In the simplest case, the interface can be created with the help of an ordinary personal computer or laptop, a suitable set of test images, and simple training organization software, which provides information and registers results. The simulator used in this experimental study is software implemented on simple software.

The sequence of test images is stored in the "Image database" folder, which holds different sets of such images in named files. Each image in the file is represented by its number, with one common name and extension type. On each image, the search objects of a given class are located randomly and practically. Their sizes are the minimum possible, but they are such that they reproduce the object's shape quite clearly. Fixation of the object's detection moment is carried out by pointing the visor at the detected object. The position of the visor is selected with the mouse so that the visor covers the detected object or its part. The viewfinder area is slightly larger than the object area. After covering the object with the brim, a mouse click is made, and the area of the bill is scanned to detect a pixel with the object's color. The detection of this pixel indicates the detection of the specified object by the recipient. That is, the visor reacts to its color. No pixel in the image should have the color of an object that has at least one pixel of that color. In this study, the workplace interface has the form shown in Figure 4.

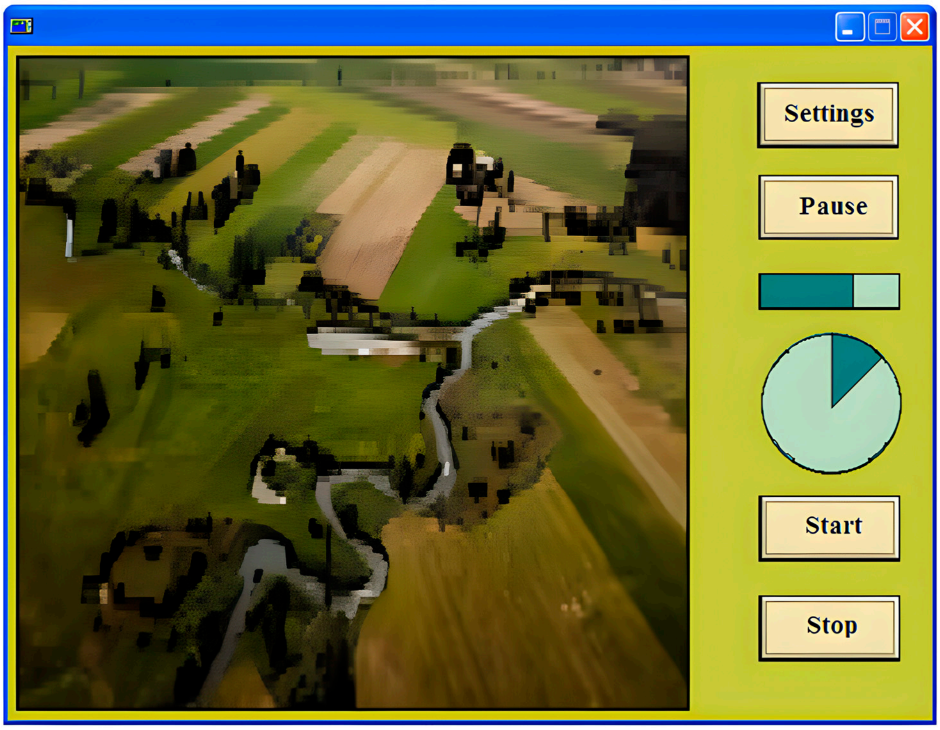

Figure 4. The appearance of the simulator interface.

The computer simulator itself actually implements software with the following functions:

1. Enable the human–machine interface.
2. The interface panel with a square window containing the information field and the corresponding control bodies is displayed on the entire screen of the computer monitor.
3. Setting up the interface includes the following: the details of the recipient are recorded; the date and time of the experiment; address and set number; the number of test images in the set; duration of exposure time of test images; the color of the object is specified; and the information field window (square or rectangular.)
4. The following results of the experiment are recorded: the start time; image number; after the image number, the time spent searching for the object of attention or missing it is indicated in this line; the number of found objects; the number of missed objects; and the total time of the experiment.
5. The detection of the search object is controlled by the color of the object, according to the specified specific signs. The rectangular area of the visor, which covers the object at the moment of detection and is controlled by the "mouse" manipulator or joystick, should be twice as large as the rectangular area of coverage of the object itself.

In addition, dynamic indicators are used to show the duration of the experiment (rectangle) and the duration of exposure to the test image (circle).

A computer simulator with this type of interface can be easily implemented in any software environment and easily reproduced in a stationery and field version. An important point, in this case, is the possibility of accurately recording experimental research data on behalf of a specific recipient and the date of the conduct before registration of the data accompanying them (that is, synchronously with the processing of the information provided by the operator) including various influencing factors from the external environment: the amplitude of acoustic signals, climatic changes, humidity, multiple vibrations, air movements, etc.

Today, computer simulators can be successfully implemented in a portable form using ordinary laptops. As information is provided to the operator, databases are used including images, which are mainly formed by the tasks and planned research scenarios.

For the organization of experimental studies, the following three options can be specified for the method of providing test images to the operator on the monitor. Each of them includes two streams of rectangular pulses, synchronized in time along the pulse front. In the first version in Figure 5, the upper sequence corresponds to a regular stream of test images, marked by light rectangular pulses of the same duration and amplitude. Here, the exposure of the tests is carried out at the same time intervals. The images of the situations are presented in a regular sequence (Figure 5).

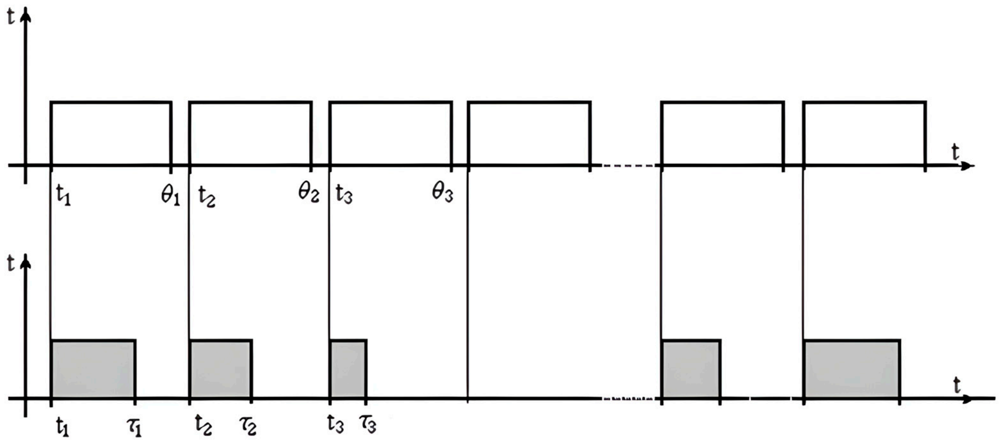

Figure 5. A regular stream of test images. Where $t_1, t_2, \ldots$ is the starting point and $\theta_1, \theta_2, \ldots$ are the moments of exposure termination; $\tau_1, \tau_2, \ldots$ are moments of decision-making by the operator.

The lower sequence of dark impulses corresponds to the duration of the search for the object of attention, its detection as the object being searched for, and decision-making. In other words, this sequence reflects the results of the human operator. Each slice of the pulse in this flow corresponds to a reaction result as the moment of decision-making by the operator. If the operator does not find the desired object in the image, then the dark pulse will be absent in the bottom sequence. In such a graphic presentation, the upper and lower pulses are synchronized along the edge. At the moment of the appearance of the test image, the stopwatch is turned on, and it is automatically turned off at the moment of the operator's decision.

In the second version, shown in Figure 6, the exposure of the test images is irregular and has different durations, but the pulse fronts of the upper and lower sequences are also synchronized. In the general case, when using an irregular flow, the duration of the pause between the upper pulses can be different. In addition, a variant is possible when the duration of the pulses of the upper and lower sequences are the same, and the duration of the pauses can be different. This means that after the operator makes a decision, the test image disappears, and the next one appears at the next moment.

In the third option, shown in Figure 7, the exposure of the image continues until the decision is made, after which the next image is displayed on the screen. The last option greatly reduces the duration of research with a limited image base since the duration of the exposure is equal to the duration of the search. In a certain case, this option has a positive value, especially for laboratory research since it allows you to process more test images during the same experimental period.

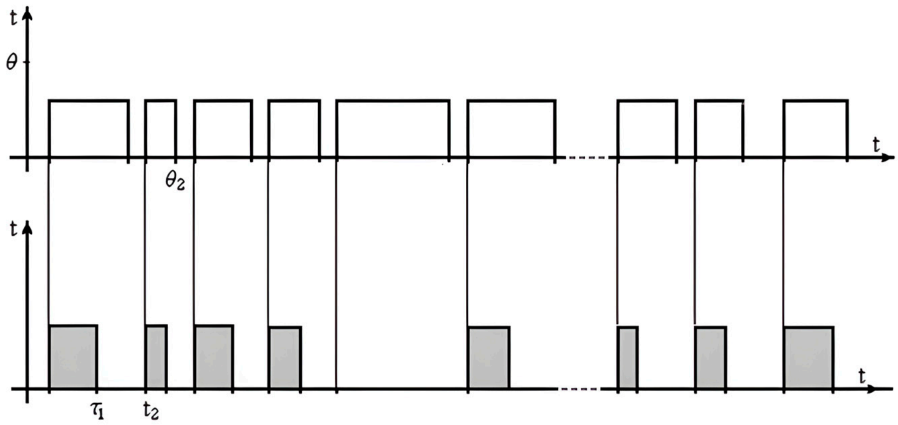

Figure 6. Irregular flow of test images.

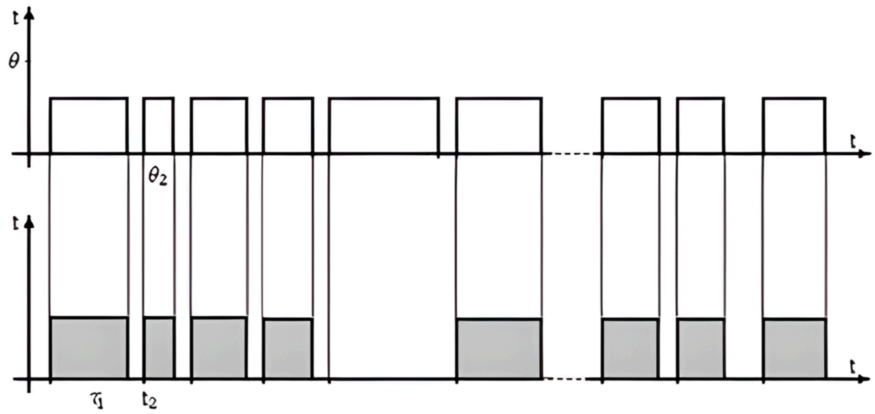

Figure 7. Irregular flow of decision-driven test images.

The considered options for providing test images and fixing decisions are not equivalent from a psychological point of view. The fact is that with regular exposure, when the operator has very quickly identified the object and made a decision, he has some time left before the exposure of this image is completed. This causes a certain relaxation, and at the moment of the appearance of a new image, the operator sharply mobilizes attention and goes into a tense state. Such an irregular change in concentration and relaxation is a negative element in operator activity. On the other hand, when the next image is presented immediately after making a decision, constant nervous tension is created for the operator due to the need to maintain concentration all the time, which is also negative. Therefore, the choice of one or another mode of providing test images on the monitor screen is not trivial, especially for long-term experiments. The display of experimental research with the help of impulse flows provides a mathematical formulation for experiments and presentation of results with mathematical models of time series, in particular, exposure of test images and object detection and decision-making.

4. Discussion

The selection of applicants for operator staff of information and search systems is essential in terms of the level of qualification and socio-psychological aspects, namely, in resistance to stressful situations. The approach given in this study is focused on studying the operator staff's behavior with minimal methodological and technical resources. Computer simulators with appropriate software and methodical support can play a role in this regard. It is impossible and dangerous to reproduce situations similar to real ones in laboratory conditions. Still, it is quite possible to create situations similar to micro-stressful ones.

The analysis of the current state of the problem of combating stress in various work situations showed that meaningful publications on the organization of experimental research with relevant recommendations and advice were not found, as they are practically unavailable. Therefore, based on the information given here about stresses and micro-stresses, the most appropriate method for analyzing the impact of stress on a human operator is the organization of research in the form of a simulation of a real work process and the operator's place in the form of a computer simulator.

The formal presentation of operator activity gives an understanding of the previous training period, some already acquired experience, the complexity of the provided information, and psychophysical resources. It also indicates the need to use sets of test images with localized objects of attention on them. In many tasks, there is a need to determine the coordinates of an object's position, which is easy to fix with the value of the coordinates of the visor area and the moment of clicking when the visor covers the object.

The development of input information, i.e., test images, is carried out by the tasks to be solved with this research. They can be either the original images or appropriately stylized, taking into account specific psychological requirements.

Such sets are prepared to simulate micro-stressful events in the operator's activities. For this purpose, images with the highest level of difficulty in detecting the object of attention are selected, especially when decision-making by a human operator is very consequential.

The proposed concept of the organization of experimental research includes the following stages:

- Study and analysis of the phenomenon of stress based on modern scientific research;
- The development of a formal description of the operator's activity in information and search systems;
- The development of specialized test images and their features in terms of the complexity and search efforts to identify objects of a given class and the creation of a computer simulator with software for providing information to the recipient, conducting the experiment itself, and recording individual results and characteristics.

Compared with other methods, the advantages of the proposed method are the following:

- A person's stressful conditions are analyzed during the working time. In previous research, analyses were carried out after the recipient had completed the work.
- The complexity of the image is changed during the experiment based on previous results (response time and moments of decision-making by the operator).

The developed method allows us to find individual parameters of the recipients such as:

- The recipient in a stressful situation;
- The mean stress time;
- The minimum and maximum time value in the stress time interval.

Therefore, these parameters are further used to classify recipients according to the level of stress resistance. The developed method can be used for detecting the attention level.

5. Conclusions

The given description of the interface of the computer simulator allows for obtaining the time characteristics of the recipient. It allows for the simulation of various functions in the operator's activity and working environment. Specific metrology in the test images provided to the operator, reflecting particular scenes of the work search process, also makes it possible to evaluate the recipients objectively and select the best among them based on the research results.

Thus, the considered elements of the laboratory study of the stress state of operator personnel ensure sufficient completeness of the definition of stress resistance precisely in the conditions of psychological, psychophysical, and ergonomic laboratories.

The simplicity and multi-functionality of the computer simulator make it a simple tool for researching micro-stresses in an operator's activities. The modeling of input information is also essential. The organization and conduct of such research must be carried out within the strict framework of a specific scenario, which in turn involves obtaining such data that, as a result of the study, will ensure the success of achieving the set goal.

The limitation of current work is the ability to deal with micro-stresses but not with panic attacks. This limitation is related to the used dataset and should be investigated separately. Future research will be related to the investigation of the after-effects of micro-stressors.

The developed method can be used by employment services to select personnel taking into account certain requirements of the profession, to determine the probability of a military serviceman fulfilling the task set before him, and to assess a person's stress resistance and ability to perform certain functions. Human-centered design, mindfulness, and micro-stress analysis in the context of test images are all important elements in the field of UX design and human–computer interactions.

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