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T.F. Shmelova, Doctor of Engineering, Professor
(National Aviation University, Ukraine)
Yu. N. Kovalyov, Doctor of Engineering, Professor
(National Aviation University, Ukraine)
V.V. Kalashnikova, Candidate of Engineering, Associated Professor
(National Aviation University, Ukraine)

System optimization of psychological and emotional compatibility of operators in air navigation system

Problem statement. Statistics point to the dominant role of the human factor (HF) influence on the total number of aviation accidents, which is about 80% [1; 2; 3]. More than 7% of aviation accidents reasons, arising from the fault of the human factor, are violations of the interaction between the flight crew [3]. A significant number of incidents and cases of aircraft damage on earth (to 34%) are also associated with the impaired interaction between different groups of aviation professionals. Therefore, the causes of most aviation accidents are associated with the psychology of aviation specialists and there are requirements for proper consideration.

International Civil Aviation Organization (ICAO) constantly develops the new concepts for decision HF problems and improves proactive, based on the risks evaluation, methods, directed on the farther decrease in the number of aviation events in the world [1; 2].

The problem of increasing the efficiency of man-machine systems (MMS) systems (reducing errors, increasing reliability, reducing the reaction time) is an important aspect of preventing various types of incidents and disasters. Joint activity plays of aviation professionals groups an important role during work flight crew and controllers' group. In features of the interaction in groups of aviation specialists the most evident in emergencies.

Increasing the psychological and emotional compatibility of components of MMS is crucial for improving the professional efficiency in the aviation system. The professional efficiency of aviation collectives includes the next steps:

- the design of equipment of the workplace;
- professional selection of specialists;
- training of specialists;
- control of the status of operators;
- selection of professional groups;
- functions distribution in group work;
- organization of the environment, which determines systemic problems of professional effectiveness, etc.

The purpose of the publication is the developments of the multifunctional model for determining the effectiveness of professional activity of Air Navigation System (ANS) operators and presentation methods of optimization of psychological compatibility, as well as to assess their contribution to the efficiency of MMS.

Main part. The authors adhere to the specific approach, distinguishing it from the generally accepted theory of "HF". The theory of the HF is gradually developed starting from the requirements of professional skills for operators and nowadays been had a stage effectiveness and safety in aviation systems. There are many circulars, documents and reports of International Civil Aviation Organization (ICAO) presented famous conceptual models of the HF, such as: SHEL (Software, Hardware, Environment, Liveware); SHELL, the Threat and Error Management (TEM); SHELL-T, SHCHELL's models; Reason Swiss Cheese's model of latent conditions, and Safety Balance models [1; 2].

According to them, aviation accidents are the result of a combination of active and latent errors. In the center of the model is a person (Liveware - L), the most critical and most flexible component in the system to which other components of the system must be carefully matched. Now the HFs model added new components such as T (Team), C (Culture), TEM (Threat and Error Management), SMS (Safety Management System) if stress and eventual breakdown in the system are to be avoided [1]. Now important are concepts for optimal solutions of aviation specialists such as Performance-Based Approach (PBA), Collaborative Decision Making (CDM), System-Wide Information Sharing and Management (SWIM) by trajectory [1]. Also, ICAO encourages aviation communities to recognize the importance of adherence to the single global approach for safety improvement and monitoring [1; 2]. An approach, founded on the characteristics (PBA) [2], based on the next three principles: the strong focus on desired/required results; decision making (DM) is driven by those desired/required results; reliance on facts and data for DM. ICAO constantly develops and improves proactive, based on the risks evaluation, methods, directed on the farther decrease in a number of aviation accidents in the world. Herein the principle "using facts and data while DM" admits, that tasks shell comply with the widely known in Western management criteria SMART (specific, measurable, achievable, relevant and time-bound). Such a level of accuracy of tasks determination can be achieved only using the way of consistent and structural description of inhomogeneous human, technical, professional, psychological, emotional and organizational factors.

In order to achieve this matching, an understanding of the characteristics of this central component is essential. People are subject to considerable variations in performance and suffer many limitations, most of which are now predictable in general terms.

The authors have presented stages of the evolution of the HF's models associated with the appearance of new system components and approaches to the diagnosis of operator errors [4; 5]:

– Professional "*skills*" of human-operators (H-Os); behavior of H-Os and definitional of H-O's errors.

– Cooperation of H-O's in the "*team*"; interaction of H-O's in the team; error detection of H-O's in the team.

– Influence of "*culture*" on H-O's. Safety in the aviation system and error prevention.

– Safety Management in the aviation system. Safety "*balance"* models and minimization of errors of H-O's.

– Optimization in MMS, "*collaborative*" DM and professional effectiveness of H-Os.

So, the *methodology* of research and analyses the professional effectiveness of specialists in ANS include next steps:

1. Systemic analysis and formalization of the influence of all factors on the H-O of ANS.

2. To analyze the professional efficiency of H-Os of aviation system:

- the "psychological portrait" of operators in the professional field (pilot, controllers, drones operators, engineering staff);
- professional selection of specialists before work for using tests and "psychological portrait";
- on-line diagnostics of the operator's emotional state in professional activity;
- the "emotion portrait" of specialists in the professional skills;
- the diagnostics of emotional state deformation in the professional activity;
- the stability of the MMS under various conditions of the human operator in the professional activity and determine the "phase portrait" of a specialist in the professional field.

3. Development of new systems for optimal work in aviation enterprises (artificial intelligence systems; virtual training and education system (VTE) – Individual, Integrated & Synchronized VTE systems for pilots, dispatchers, drones operators, engineering staff, etc.; the intellectual automated control system (IACS) of human state monitoring systems.

4. Optimization models of DM by H-O (pilots, air traffic controllers, engineers, Remotely Piloted Aircraft System's operator, etc.

Consider the content of analysis the professional effectiveness of specialists in ANS for using a theory of self-organization of complex systems.

Application of the theory of self-organization of complex systems to the study of the organization of human consciousness, along with traditional methods of research of the H-F [4; 6; 7], allows determining the channels of human interaction with the environment, their grouping, specific objects of perception of each channel, priorities and weight factors (Table 1).

Table 1

The system of channels of perception by the person of the surrounding world

Levels and objects of perception	**Characteristics of perception**	**Channels**
Level 1 - Unity	Man and the environment are not separated, but the potential of this potentially exists	Intuition 1
Level 2 - separation	Awareness of themselves as self-sufficient and is separated from the second world	+Ego 1
Level 3 - effects and reactions	Influence on the surrounding world, corresponding reaction.	+Will and mind 2
Level 4 - space and time	Arranging influences and reactions by categories of space and time	+ Desire, feeling and reason 2 * 3 (tracking forms and changes (ekstero-, propryo-, interotseptory)

Level 5 – main colors, sounds, aromas, etc.	Organizing perceptions by sensory organs	+ Sensory perceptions, 2 * 3 * 5 (?)
Levels 6, 7 - colours, tones, etc.	Differentiation of tones and nuances	+ Distinguishing tones, 2 * 3 * 5 * 8 (?)

Correlation between channels of perception of the person of the surrounding world, psychotypes, methods of their perception of information, methods of activity, roles in public life, conditions of comfort is determined. The channels are present in all people; individual priorities may be several channels that should be considered when designing information display systems and controls.

Display devices and controls. From the Table 1, the appropriate coding methods for information display systems, as well as the organization of control devices, are derived (Table 2).

Table 2

Encoding data organization and control devices

Psychotype	**The data coding method**	**Control device**
balanced personality	any type	any type
viewer	compositional unity	touch-screen
selfish	figures selection on background	voice commands
fighter	contrast of figures or colors	switcher
enterprising researcher	analog, digital	helm, slider, keyboard
artistic personality	colors	color scale

To evaluate the efficiency of these recommendations, there are some methods, such as counting the duration of visual fixation; expert evaluation; measurement of the speed and errors of the operator when working with a full-scale sample of the display system and control devices. Note that the reaction time of the operator, judging by the performed evaluation [7], can be potentially reduced by 3.5-4 times with a significant reduction in the number of errors.

Comfortable habitat. Based on table 2, note, that each psychotype has own requirements to the environment. Table 3 provides possible stylistic solutions, that implement these requirements.

Table 2

Possible stylistic solutions for a comfortable environment

Psychotype	**Stylistic solutions**
balanced personality	any style, which created aesthetic excellence at all levels of habitat
viewer	eco-and biostiles
selfish	modern interpretations of the Baroque
fighter	variations of the transformative space
enterprising researcher	constructivism, functionalism
artistic personality	Art Nouveau, Postmodernism, Art Deco

In [7], they were specified for the design of housing, in particular, with the simultaneous living of people of various psychotypes. Expert assessments have shown improvements in psychological comfort. It can be assumed that the implementation of such recommendations in the design of the host environment will have positive effects - reduce fatigue, increase productivity, improve concentration, reduce the number of errors. However, no experimental verification of these assumptions was made.

Distribution of functions in group management. Representatives of individual psychotypes play different roles in public life. Therefore, it is expedient to select operators for group work to perform the most natural functions for them (Table 4).

Table 4

Distribution of functions in a group of operators depending on the psychotype

Psychotype	**Functions in a command of operators**
balanced personality	generation of non-standard solutions
viewer	prediction of abnormal situations
selfish	team management
fighter	quick simple corrective actions
enterprising researcher	slow complicated corrective actions
artistic personality	adjust emotional background

The effectiveness of the implementation of these recommendations should be evaluated for each one system in experimental verification.

Monitoring of the emotional state of aviation specialist and diagnostic of deformation of the emotional state in professional activity. For operational determination of operator emotional state deviations and bias in DM in risk applied the concept of human mental activity, which is based on a property of consciousness delay or accelerates the flow of subjective time relative to real time. Deformation of the emotional state defined using a priori models of operators, based on actual material posterior studies of investigating aviation accidents received by the International Aviation Committee (IAC). There are three types of operator emotional activity: spontaneous (optimal) type of activities; emotional type of activities; reasonable type of activities. Spontaneous (optimal) type of piloting activities is characterized by accuracy and timeliness of pilot actions in unusual situations. Low emotional stress, a pilot transition to potentially dangerous mental activity: emotional type of activities – advanced actions relative to real-time and reasonable type of activities – delayed actions relative to real time. Spontaneous piloting provided mostly automatic mental processes and is characterized by correctness pilot actions within the previous experience. These pilot actions are synchronized in time with the physical process of moving air vehicle that is agreed between the real (physical) and subjective (mental) processes in time and space, or behind no more than two seconds. Pilot actions in the optimal (spontaneous), emotional and reasonable modes are defined by the phase trajectory of ailerons deviation and rudder direction [4].

The authors have developed the method of diagnosis of the current emotional state of the operator during the professional activities.

Algorithm for identifying the current emotional state operator

1. Finding the center of the distribution of the random variable as points with coordinates X_0 and Y_0:

$$X_0 = \frac{\sum_{i=1}^{n} X_i}{n};\ Y_0 = \frac{\sum_{i=1}^{n} Y_i}{n},$$

where X_i, Y_i – are the coordinates of points; n – is a general number of points.

2. The distance from the founded point to other points:

$$d_i = \sqrt{(X_i - X_0)^2 + (Y_i - Y_0)^2}.$$

3. Dispersion:

$$D = M(d^2) - M^2(d);\ M(d^2) = \sum_{n}^{i=1} d_i^{\,2} p_i;$$

$$M^2(d) = (\sum_{n}^{i=1} d_i p_i)^2,$$

where $M(d^2)$ – is a mathematical expectation of the square of the random variable; $M^2(d)$ – is a square of mathematical expectation of a random variable; p_i – is the probability that a random value will be precisely this value.

4. Identification of emotional portrait of *j*-operator using models of emotional state identification for spontaneous, emotional and reasonable types of operator activity, obtained by the phase trajectory moving ($F_i=f(D_{ij})$).

5. Identification of the current emotional state of *j*- operator, matching his portrait and emotional limits corresponding variances ($F_{min}=f(D_{min})$, $F_i=f(D_{ij})$, $F_{max}=f(D_{max})$) the type of emotional activity of operator: $F_{min}=f(D_{min}) < F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

6. Diagnosis of deformations of emotional experience (state) as a transitions to dangerous types of H-O activity (reasonable or emotional): $F_i=f(D_{ij}) > F_{max}=f(D_{max})$, $F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

7. Determination of the type of operational activity in the case of mental deformations of emotional state using models of identification of spontaneous, emotional and reasonable types of operator activity and determining appropriate variances: $D_i>D_{max}$; $D_i<D_{min}$.

8. Determination of the MMS stability using the Nyquist criterion with consideration of the dispersions by the operative model of the emotional state.

9. An indication of diagnostics results of pilot's current emotional state in flight using dynamic panel display of digital data encoding.

The information about the emotional state of ANS H-O can be used in audits of programs safety LOSA "Line operations Safety Audit", which are used to collect

data on the behavior of crew members and situations during a real flight. LOSA is a tool for collecting safety data during normal airline operations. Monitoring routine operations, the cornerstone of the LOSA process, addresses an important aspect of safety auditing, namely, that risks and human error can never be completely eliminated. Accident investigation concentrates on failures, which are important for discovering major breakdowns in the system, but failures are rare events. Self-reporting of incidents and potential hazards preceding major accidents can be limited because personal biases about behavioral norms may result in overlooking significant actions, and there are always concerns about professional consequences

Conclusion

The system of improvements of various aspects of the functioning of ergatic systems, based on increasing the psychological compatibility of its components, as well as the evaluation of the effectiveness of such measures, is proposed. Further work in this direction is connected with experimental verification, as well as the implementation of new concepts of disasters and the instruments of their prevention, which followed by a systematic approach.

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