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Increasing the reliability of stress tolerance prediction as part of aptitude screening of flight specialists

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Abstract. Aim. *The paper describes a research aimed at improving the reliability of stress tolerance prediction as part of aptitude screening (AS) of flight school applicants using a proprietary objectifying method of Stress Tolerance Assessment. Stress tolerance (ST) is an important psychophysiological professional quality and serves as one of the factors ensuring both successful flight training, and further professional flight work. However, the methods recommended in regulatory documents for the purpose of ST identification as part of AS are not efficient enough and are affected by subjective factors. Therefore, an objective and thus more efficient method is still required.* **Methods.** *The method was developed based on the analysis of subject-matter literature and own experience. Stress stimuli and methods of indicator recording were selected based on their empirical verification. The stress-inducing property of the stimuli was confirmed by the pulse rate increase by 40 – 100% and higher, associated behavioural manifestations and significant dynamics of mental productivity in the course of tests. Out of the methods of mathematical statistics, the authors used correlation analysis.* **Results.** *The method of ST assessment is based on the Reakor multifunctional psychophysiological system by the Medicom MTD research and development company from Taganrog, Russia, with a proprietary procedure built in the system's software. As stress stimulus material and for performance assessment, arithmetically complicated problems were selected, whose solutions involve a larger portion (areas) of the brain than verbal tests. In order to eliminate the effect of habituation and learning, the arithmetic tests were displayed one by one on a computer screen in a random order. The 3-4-second time interval between individual problems was selected based on premises of aviation psychology and tests conducted on a group of students. The sample consisted of 1135 male applicants to the higher flight school in 2016. Correlation analysis shows that the correlations between the external criterion indicators (successful simulator training and flying practice) and the integrated ST indicator are statistically significant: the higher is the ST indicator measured in the course of AS using the respective method, the higher are the expert estimates of the simulator training and flying practice.* **Conclusion.** *Thus, the conducted research showed that the application of the developed method of ST assessment in the course of higher flight school AS ensures higher predicted stress tolerance in the selected candidates as the psychophysiological factor of professional efficiency and reliability of flight personnel.*

Keywords: *aptitude screening, professionally important qualities, flight personnel, stress tolerance, dependability.*

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Introduction

Despite the immense technological progress, the matter of in-flight reliability and safety holds relevant and attracts the attention of researchers in various fields of knowledge [1 – 8]. One of the most important features of the flight personnel professional activity is the situations of stress. Despite the ongoing improvement of the aptitude screening (AS) of flight school applicants, about 50% of flight student expulsions in the recent past, and 20% in the last few years [9, 10] were due to poor air training results. Stress tolerance (ST) is one of the most important psychophysiological professional qualities of a pilot that contribute to the flight safety. ST is understood as a complex, multilevel and comprehensive professional quality, a system of individual psychological, psychophysiological and socio-psychological properties that allows successfully resisting extreme negative environmental factors while maintaining an optimal mental and emotional state and the ability to carry out a certain activity at an adequate physiological "cost" and maintained high level of efficiency. The systemic nature of the ST properties is expressed in the fact that the individual human characteristics are manifested only in unity and interaction with each other. Currently, in accordance with the regulatory requirements, the ST assessment as part of aptitude screening of flight school applicants primarily involves questionnaire survey [11, 12]. The experience of such methods' application for the purpose of flight school applicants ST assessment has shown their insufficient informative value, sometimes data inconsistency, inferior objectivity and susceptibility to subjective factors. The flight school applicants' ST assessment is also very important due to the fact that it defines the quality of not only their flight training, but subsequent flight activity as well, thus being, among other factors, a contributor to the professional dependability [9, 13].

Problem definition

It is not uncommon for those who performed well under normal conditions to underperform in a stressful situation. The primary indicators of stress tolerance include the capability to retain the ability for adaptive activity (keeping or improving the working capacity) in a critical situation [3, 10, 14]. According to literature, informational overload is one of the main sources of a pilot's professional stress [4, 15, 16]. Therefore, it is logical to assume that the mental performance indicators registered under experimental stress will be informative criteria for predicting ST in an actual professional emergency situation [14, 15, 16]. The limiting factors in the development of the method of predictive evaluation of ST as part of AS are the absence of sophisticated equipment for simulating stress situations and the 14-16-minute time limit for one survey with the potential number of applicants of 1200 or more. The basic premises of the method under development are based on the works of B.V. Lomov, V.A. Bodrov, L.A. Kitaev-Smyk, V.A. Ponomarenko, V.L. Marishchuk [14, 15, 17, 18, 19]. The following problems were solved in the course of the method's development: 1) conditioning of the stress stimulus (stimulus complex) that causes the experimental stress; 2) selection of the ST indicators in the experimental stress (dynamics of the mental productivity in the course of testing, its physiological cost, behavioral reactions).

Material and methods

The developed method is intended for AS of flight school applicants. As stress stimulus material and for performance assessment, arithmetically complicated problems were selected, whose solutions, according to literature, involves a larger portion (areas) of the brain than verbal tests [20, 21]. This corresponds to literary sources [15, 16, 22] that confirm that the primary cause of stress in flight personnel is information overload [15, 16, 22], which is also associated with the fact that in today's airplanes the instruments are digital rather than analogue. Additionally, in order to increase the stressfulness of the test situations, the process of problem-solving was complicated by information interference (sound of a metronome, a tense radio exchange between an air traffic controller and a pilot over a failed engine, etc.) delivered through headphones. In order to eliminate the effect of habituation and learning [23], the arithmetic tests were displayed one by one on a computer screen in a random order. The 3-4-second time interval between individual problems was selected based on premises of aviation psychology and tests conducted on a group of students. The test problems and methods of indicator recording were selected on the basis of their empirical verification as part of the AS of flight school applicants of the years 2013 to 2016. The stressfulness of the developed test was confirmed by the 40-100% or higher heart rate, as well as associated behavioural manifestations and significant dynamics of mental productivity in the course of the tests [24, 25]. For the present study, the latest version of the method was chosen, that was used in 2016 to survey 1135 male applicants. In 2020, upon receiving the results of flying practice of 562 students of that admission year, the method's criterion validity was verified per that external criterion. Out of the methods of mathematical statistics, the authors used correlation analysis.

Results and discussion

The method of ST assessment is based on the Reakor multifunctional psychophysiological system by the Medicom MTD research and development company from Taganrog, Russia, with a proprietary procedure built in the system's software.

The ST assessment procedure consists in the mental productivity survey in the course of three cognitive tests in parallel with physiological parameters registration (heart rate) at all stages of the survey, as well as observation of the behavioral manifestations in a stressful situation. The cognitive tests include two modified versions of "Arithmetical calculations", the "Arithmetical calculations 1" (AC-1) and

Table 1: The integral estimation of the ST based on multidimensional scaling

ST indicator (integral estimate)	154.58 and more	132.48 – 154.57	120.63 – 132.47	120.62 and less
Description	Predicted practical reliability in emergency situations: low. Low stress tolerance. Not recommended for flight training	Predicted practical reliability in emergency situations: satisfactory. Satisfactory stress tolerance. Conditionally recommended for flight training	Predicted practical reliability in emergency situations: high. High stress tolerance. Recommended for flight training.	Predicted practical reliability in emergency situations: very high. Very high stress tolerance. Highly recommended for flight training

"Arithmetical calculations 2" (AC-2), as well the specially developed method of "Addition of numbers". Each of the tests, the AS-1 and AS-2, consists of 20 problems. Essentially, the method consists in the verbal solution of the arithmetical problems with integers from 1 to 25. The modification of the method consists in the fact that each individual problem includes two actions, is displayed to the tested student with a time intervals from 4 to 3 seconds, i.e. the problem is to be solved within a specified time limit: the first 10 problem are displayed with the time interval of 4 seconds, the last 10 problems are displayed every 3 seconds. In the process of test performance, additional (psychological) stress is introduced: besides the artificially created time pressure, the problems are accompanied by sound interference in the form of metronome sound delivered through headphones.

There are 5 possible answers for each problem. It is required to choose the correct one and name the letter of the corresponding line. The tested person is to perform arithmetical operations in the order as they are written, from left to right, disregarding the rules of arithmetical calculations. After finding the answer, the tested person is to say the number of the problem and the letter of the corresponding answer line, e.g. "one – C", "two – B", etc.

The "Addition of numbers" (AD) test consists of 60 arithmetical problems, in each of which it is required to summarize 5 one-figure numbers displayed on the monitor every 3.5 seconds. The tested person is to find the sum of 5 numbers and say the answer corresponding to the number of the problem, e.g. "one – 19", "two – 25", etc.). Additional stress is created in the process of the test performance, i.e. through time shortage (only 3.5 seconds are allocated for each problem) and sound interference delivered through headphones (radio exchange between an air traffic controller and a pilot regarding an engine failure).

The answers are given orally, as the hands of the tested person carry special sensors that register physiological signals (heart rate), which makes giving written answers impossible. The oral form of the answers also has a heuristic dimension, as it allows observing the tested person's verbal behavior and monitoring his/her emotional tension during the test.

The physiological "cost" of the activity is assessed by the shifts in the physiological indicators (heart rate) at all stages of testing and their persistence after the removal of stress at the stage of "rest". The registered behavioral reactions include the varied emotional stress response: tremor, stuttering, motor and verbal retardation, freezing, hyperactivity (unnecessary fidgeting), mimic, skin vegetative and postural behavioral reactions. The qualitative behavioral characteristics were converted into quantitative indicators according to the qualimetric approach [26].

A comprehensive ST conclusion is made by integrating the parameters of all indicators. The integral ST estimation is based on expert analytics involving multidimensional scaling that was demonstrated by leading aviation psychology experts to be the optimal method of practical assessment of the professionally important qualities of a military pilot [15, 27]. The integral estimation allows – on the basis of indicators standardized as part of pilot research [4, 28, 29] – ranking each tested person into one of the four professional aptitude groups in terms of the degree of ST: most fit, fit, conditionally fit and unfit, as it is shown in Table 1.

Upon the completion of the ST assessment procedure, for each applicant, a test report is made that includes the results with a description of individual psychological and psychophysiological features and generated comprehensive conclusion regarding the professional aptitude in terms of ST.

The method's validity was confirmed by the research of the correlation between the integral ST estimate and the indicators of the external criterion, i.e. indicators of successful practical simulator training and successful flight practice.

The study of the correlation between the ST indicators and successful simulator training was conducted as part of a preliminary verification of the method's criteria validity [30]. At the end of the simulator training, instructors assess

Table 2. Correlation coefficients between the integral ST estimate and the external criterion indicators of simulator training (n = 562)

External criterion indicator name	Integral ST estimate
tension during simulated flight	-0.316
actions in special cases	0.276

Table 3. Quantitative distribution of the students (admission year 2016) among flight training performance groups in 2020.

Sample of students (number, percentage)	Number of individuals:			
	1-st group ("strong")	2-nd group ("above average")	3-rd group ("average")	4-th group ("below average", "weak")
n = 562	41	136	272	113
100 %	7.3	24.2	48.4	20.1

the students in terms of the rate of development and stability of skills, coordination of movements, distribution of attention, actions in special cases (failure, engine fire, etc.) and other abilities they have shown during their "flights" in the simulators, which was chosen as the external criterion. The comparison of the ST indicators with the stress indicators and students' actions in the special cases of simulator "flights" brought out significant correlations ($p < 0.05$) between the integral ST estimate and the external criterion that are shown in Table 2.

The analysis of the data presented in Table 2 establishes that the correlations between the integral ST estimate and the instructors' assessments are statistically significant (if $p < 0.05$). That means that the higher is the ST measured as part of AS using the ST assessment method, the lower is the students' stress indicator and better are the students' actions in the simulated special cases.

The initial flight training (flying practice) is the more accurate external criterion for confirming the method's predictive valuation. In 2020, the students of the 2016 year of admission demonstrated similar results during the flying practice at the training bases of the Krasnodar Higher Aviation School of Pilots.

The flying practice performance was assessed by the flight instructors in the form of the following ratings that characterize students in terms of the flying aptitude and quality of flight training:

- a strong student with very good flying aptitude;
- an above-average student with good or above-average flying aptitude;
- an average student with an average flying aptitude;
- a below-average student with a below-average flying aptitude;
- weak student with a very poor flying aptitude.

The flying practice rating was distributed in accordance with the regulatory document [12] as follows:

- expert assessment "strong" corresponds to the 1-st performance group, the occupational aptitude class I;
- expert assessment "above average" corresponds to the 2-nd performance group, the occupational aptitude class II;
- expert assessment "average" corresponds to the 3-rd performance group, the occupational aptitude class III;
- expert assessment "below average" corresponds to the 4-th performance group, the occupational aptitude class IV.

The quantitative distribution of the students among flight training performance groups is shown in Table 3.

Examining the students' distribution among flight training performance groups in accordance with the normal distribution law will reveal a sample bias in the direction of "average" and "below average and weak". In order to mitigate the statistical bias, the 1-st and 2-nd groups of students were merged. After that, the sample of students (n = 562) was split into 3 groups as follows: the 1-st and 2-nd groups are 273 students; the 3rd group is 207 students; the 4th group is 82 students.

According to this approach, the distribution of students by their integral ST estimate was also done into three groups: the 1-st group includes those "recommended and highly recommended" for the flight training; the 2-nd group includes those "conditionally recommended"; the 3-rd group includes those "not recommended". It should be noted that in the third year of study students undergo initial flight training that is concluded with a solo flight on a trainer aircraft. In the course of further training involving basic and advanced flight training, students develop flying aptitudes. The proportion of students with high flying aptitudes grows, while the proportion of "weak" students significantly decreases.

The research of the correlation between the obtained external criterion indicator (results of the flying practice) and the integrated ST indicator has shown its statistical significance (if $p < 0.05$). The distribution of the flying practice performance indicators depending on the ST indicator values is shown in Table 4.

The data shown in Table 4 demonstrate that the students with high ST have higher ratings in simulator training and expert assessments of flying practice by flight instructors.

Table 4. Average values and confidence intervals of flying practice assessments in terms of ST (if $p < 0.05$, the denominator shows the sizes of the groups).

Test sample	The flying practice rating based on the ST assessment method		
	1-st ST group	2-nd ST group	3-rd ST group
students of the 2016 admission year; n = 562	$\frac{3.32 \pm 0.09}{273}$	$\frac{3.09 \pm 0.12}{207}$	$\frac{3.02 \pm 0.17}{82}$

However, the statistical validity ($p < 0.05$) of such differences is manifested when we compare opposing groups: students with high ST indicators, the 1-st group, have the expert assessment of flying practice "strong", while students rated as "weak" and "below average" by the experts have low ST indicators, the 3-rd group.

Conclusion. Thus, the above correlation analysis showed that the correlations between the integrated ST indicator and external criterion indicators are statistically significant (if $p < 0.05$): the higher is the ST indicator identified using the respective method, the higher are the expert estimates of the flying practice by the flight instructors (reliably if $p < 0.05$). Currently, the method of Stress Tolerance Assessment is undergoing expert verification for the purpose of possible inclusions into AS regulatory documents. Therefore, the application of the developed method of ST assessment in the course of higher flight school AS ensures higher predicted ST in the selected candidates as the psychophysiological factor of professional efficiency and reliability of flight personnel.

References

1. [Concept of flight safety of the Armed Forces of the Russian Federation]. Approved by the Ministry of Defense of the Russian Federation on 31.05.2017. Moscow: Aviation Flight Safety Service of the Armed Forces; 2017. (in Russ.)

2. Arinicheva O.V., Malishevsky A.V. Improving the reliability of professional psychological selection of aviation specialists. *Dependability* 2019;19(1):40-47. https://doi.org/10.21683/1729-2646-2019-19-1-40-47.

3. Gander D.V., Vorona A.A., Ponomarenko V.A. et al. Methodological and theoretical premises of the psychological research of the flight work at the current stage of development of aviation. *Psikhologiya i Psikhotekhnika* 2016;11:906-912. DOI: 10.7256/2454-0722.2016.11.22442. (in Russ.)

4. Krachko E.A., Krasilnikov G.T., Malchinsky F.V. et al. Reliability of forecast of successful flight training based on professional psychological selection. *Dependability* 2018;18(3):27-30. https://doi.org/10.21683/1729-2646-2018-18-3-27-30.

5. Lapa V.V., Ponomarenko V.A., Chuntul A.V. [Psychophysiology of flight safety]. Moscow: [Association of Law Enforcement Journalists]; 2013. (in Russ.)

6. Nikiforov D.A., Vorona A.A., Bogomolov A.V. Technique of estimation of potential unreliability of actions of the pilot. *Life Safety* 2015;7:7-16. (in Russ.)

7. Plotnikov N.I. The bases of human – operator dependability theory. *Dependability* 2015;2:94-97. DOI:10.21683/1729-2640-2016-16-3-3-7.

8. Ponomarenko V.A. [Flight safety, the pain of aviation]. Moscow: Flinta; 2007. (in Russ.)

9. Ponomarenko V.A. [A professional's spiritual psychology]. Moscow: PER SE; 2004. (in Russ.)

10. Alioshin S.V. [Safety and stress]. In: Kozlov V.V., editor. [Human factor: new approaches to air accident prevention: a collection of articles]. Moscow; 2000:59-65. (in Russ.)

11. Zarakovsky G.M., Lazutin V.I., editors. [Fundamentals of aptitude screening: a teaching aid]. Moscow: Voenizdat; 2005. (in Russ.)

12. [Guidelines for the organization and conducting of aptitude screening in the military education establishments of the Ministry of Defense of the Russian Federation]. Moscow; 2002. (in Russ.)

13. Blaginin A.A. [Professional reliability of pilots]. In: [Physiology of flight work: a textbook]. Saint Petersburg: Nauka; 1997. (in Russ.)

14. Marishchuk V.L., Evdokimov V.I. [Human behaviour and self-direction under stress]. Saint Petersburg: Izdatelskiy dom "Sentyabr"; 2001. (in Russ.)

15. Ponomarenko V.A. [The psychology of the human factor in a hazardous occupation]. Krasnoyarsk: Polikom; 2006. (in Russ.)

16. Pokrovsky B.L. [Emotional stress]. In: Ponomarenko V.S., Vasiliev P.V., editors. [Functional state of a pilot in extreme situations]. Moscow: Poliot; 1994. (in Russ.)

17. Lomov B.F. [Methodological and theoretical problems of psychology]. Moscow: Nauka; 1984. (in Russ.)

18. Bodrov V.A., Orlov V.Ya. [Psychology and dependability: human being in control systems]. Moscow: Institute of Psychology of the RAS Publishing; 1998. (in Russ.)

19. Kitaev-Smyk L.A. [Psychology of stress]. Moscow: Akademichesky proiekt; 2009. (in Russ.)

20. Roik A.O., Ivanitsky G.A. Neurophysiological model of cognitive space. *Journal of Higher Nervous Activity* 2011;60(6):688-696. (in Russ.)

21. Aydarkin E.K., Fomina A.S. [Research of the dynamics of spatial synchronization cerebral biopotentials while solving complex arithmetical problems]. *Journal of Health and Life Sciences* 2012;3:91-106. (in Russ.)

22. Bodrov V.A. [Information overload: a study guide for higher education establishments]. Moscow: PER SE; 2000. (in Russ.)

23. Aliushin M.V. [Minimizing the habituation effect during psychological testing]. *Voprosy Psychologii* 2015;3:153-160. (in Russ.)

24. Krasilnikov G.T., Krachko E.A., Malchinsky F.V. [Development of the method for identifying the stress tolerance in the applicants to a higher military aviation school]. In: Proceedings of the XV South-of-Russia Research and Practice Conference Innovation Technology in the Educational Process. Krasnodar: MAC, Subsidiary of AF MESC. 2013. Vol. 2. 173-181. (in Russ.)

25. Krasilnikov G.T., Krachko E.A., Malchinsky F.V. [Matters of research of the experimental stress of hazardous occupations]. In: Proceedings of the Anniversary Conference From the Origins to the Present Day (130 years of the Moscow University's Psychological Society) in 5 volumes. Vol. 5. Moscow. 2015. 9-21. (in Russ.)

26. Kosachiov V.E., Agopov I.V., Usov V.M. [Qualimetric approach to the study of professionally important qualities]. In: [Development of the ideas of B.F. Lomov in the research of labor and industrial psychology]. Moscow; 1992. (in Russ.)

27. Ponomarenko V.A., Vorona A.A., editors. [Formation and development of professionally important qualities in military students in the course of training in the HMASP]. Moscow: Voenizdat; 1992. (in Russ.)

28. Krachko E.A., Krasilnikov G.T., Malchinsky F.V. [Psychophysiological aspect of the research of the stress tolerance in flight personnel]. In: Proceedings of the XXIII Convention of the I.P. Pavlov Russian Physiological Society. Voronezh: Izdatelstvo Istoki. 2017. 1278-1279. (in Russ.)

29. Krachko E.A., Krasilnikov G.T., Malchinsky F.V. [Development of a stress-inducing stimulus for the method of stress tolerance assessment]. In: Proceedings of the Science and Practice Conference Dedicated to the 20-th Anniversary of the Department of Military Psychophysiology of the Military Medical Academy: Psychophysiology of Occupational Health. Saint Petersburg: VMedA. 2017. 192-197. (in Russ.) 192–197 [in Russian].

30. Krachko E.A., Krasilnikov G.T., Malchinsky F.V. [Research of the stress tolerance in the applicants to a higher military school of pilots]. *Izvestia of the Russian Military Medical Academy* 2019;38(3):34-41. (in Russ.)

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The authors' contribution

Krachko E.A. Review and analysis of the state of the art of the problem under consideration. The theoretical aspect of the paper, development of the method of Stress Tolerance Assessment, pilot trial of the method of Stress Tolerance Assessment and statistical processing of the obtained results.

Krasilnikov G.T. Review and analysis of the state of the art of the problem under consideration.

The theoretical aspect of the paper, development of the method of Stress Tolerance Assessment, pilot trial of the method of Stress Tolerance Assessment.

Malchinsky F.V. Review and analysis of the state of the art of the problem under consideration, development of the method of Stress Tolerance Assessment, organization of the pilot trial of the method of Stress Tolerance Assessment.

Medvedev V.I. Review and analysis of the state of the art of the problem under consideration, development of the method of Stress Tolerance Assessment, organization of the pilot trial of the method of Stress Tolerance Assessment.

Conflict of interests

The authors declare the absence of a conflict of interests.