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EXPERIMENTAL VERIFICATION OF PSYCHOPHYSIOLOGICAL PERFORMANCE OF A SELECTED FLIGHT PERSONNEL AND SW: PRESURVEY FOR TRANSPORT SAFETY

Summary. Flight personnel have various factors that cause high psychological stress during the performance of flight tasks, thereby influencing their psycho-physiological experience, which may be a cause of a breach of air traffic safety. The paper presents the results of an experimental verification of task management under load, which allowed selection of probands from a sample of 100 participants in the presurvey. Overall, 70% of the probands achieved better results than the minimum level of success of simulated and the complex tasks, 60%. The main aim of the experiment, the presurvey, is to verify and prepare a final version of sets of test tasks in the field of measuring the psychophysiological performance of the candidates for aviation personnel and to complete the creation of a technical device and the software tool for these processes. The software will be filed for the patent protection of copyrights and subsequently used for solving an approved research project supported by a grant from the Agency for Science and Research of the Slovak Republic.

1. INTRODUCTION

The need to identify the level of influence of factors influencing the change of physiological parameters and hence on the performance of aviation personnel has led to the application of the various methods of measuring, collecting and processing of physiological data. The individual load measurement techniques can be divided into three categories: performance, subjective evaluation and physiological measurement. In complex roles, however, exercise cannot be evaluated by performance or subjective assessment. Therefore, it is necessary to objectify the assessment of the load based on physiological measurements.

With increased stress, the stress leads to parasympathetic attenuation and increased sympathetic activity. The manifestations of this situation are changes in the heart rate, respiration, blood pressure and other physiological values [1].

On the contrary, the motor activity of a hand when handling a tool or device can provide us with information about how precise movements are connected to its operation. It can also be determined whether the hand is shaking. The tremor may be psychogenic (for example by stress) or as a consequence of various illnesses [2]. Through the body temperature, it is also possible to recognize the unwanted or unusual human physiological conditions. The increased body temperature or fever can point to some of the many diseases, but we can see an increase in this parameter even when weighing excessively when the body tries to compensate for this condition by thermoregulatory mechanisms such as sweating. Other physiological factors of elevated

temperature can be menstruation or psychological disturbance. Additionally, the body temperature is not constant during the day but fluctuates [3].

Physiological measurements can therefore serve as good indicators of psychological stress [4]. From the point of view of physiological parameters, the influence of psychic state of aviation personnel on the pulse frequency and change of the heart rhythm is most often investigated. This is because it is one of the simplest measurable physical manifestations of psychic stress that activates the sympathetic activity. However, other indicators such as body temperature, EMG, motor activity and others [5] are also measured. This is evidenced by our further experience of scientific work and the studies in the selected sectors of critical infrastructure, with our emphasis on the Air Force / Aviation experience [6].

The scientific papers have shown a connection between the various physiological responses of the body, stress and performance (see also [7, 8]). The comparison of indirect breathing sensing methods (induction and impedance plethysmography, piezospor sensor sensing and piezoelectric sensing) was performed by Lanata et al. in the 2010 study [9]. These methods have been chosen because they can be embedded in a wearable form and are not annoying for the subject being measured.

The possibility of non-contact breathing sensing with the thermo camera was studied in the 2010 study by Al-Khalid et al. [10]. The method is based on the observation of a certain area of the face and the evaluation of the pictures taken with the thermo camera. Response frequency imaging techniques have been used, such as thresholding or edge detection, to suppress the unwanted noise while enhancing the thermal images.

The influence of the load on changing the breathing frequency during the simulated flight was evaluated in the work [11]. When measured, they always first measured the standardized value base. Then they followed the 11 flight tasks they watched. A mixed model statistical method was used to evaluate the connection between the difficulty of the task and the measured respiration.

The monitoring of United States Army soldiers using the NASA technology has been carried out by Cowings et al. in the 2001 study [12] and correspondingly in 2010. The aim of the study was to evaluate the sickness of a soldier moving in an army vehicle.

The database of knowledge consists of the international regulations and methodological procedures within the ICAO (International Civil Aviation Organization, e.g. ANNEX 1 Personnel Licensing etc.), EASA (European Aviation Safety Agency, e.g. Regulation (EU)No 1178/2011; Medical requirements etc.), FAA (Federal Aviation Agency of the United States, or the National Safety Board Database of the United States), and also regulations of EUROCONTROL (pan-European, civil and military organization dedicated to supporting the European aviation), the global, regional and national initiatives to address the lack of qualified aviation personnel, or the new learning technologies and training methods for the next generation of aviation professionals (NGAPs).

The scientific work is motivated by the number of publications in the field of aviation psychology and human factors as in Martinussen and Hunter [13], Vidulich and Tsang [14], Harris [15] and the publications of the European Association for Aviation Psychology.

The main aim of the experiment, the presurvey**,** is to verify and prepare a final version of sets of test tasks in the field of measuring the psychophysiological performance of the candidates for aviation personnel and to complete the creation of a technical device and software tool for these processes. The software will be filed for the patent protection of copyrights and subsequently used for the solving an approved research project supported by a grant of the Agency for Science and Research of the Slovak Republic.

2. MATERIALS AND METHODS

A key scientific tool for the solving of research tasks was the experiment and use of devices to measure the reaction time of the probands in solving the problems. A sample of probands, those interested in pre-survey who will participate in a research project with a grant from the Agency for Science and Research of the Slovak Republic, was selected from the number of 100

candidates, representing 33 students of the Faculty of Aeronautics of the Technical University in Košice. Our students study the programs 3-719 Professional Pilot, 3-722 ATC Worker and 3-721 Air Transport Management.

All those probands interested in participating in the experiment have undergone an initial stress test, which has proven successful in selecting a sample in the past to ensure uniformity. The test itself consisted of four parts (TEST 1-4). In each part of the test, our probands performed 300 tasks, with each task having an exact time of 2 seconds. Gradually each subsequent test increased the demands for emotional stability, attention and mental overload, which was manifested individually in the number of errors.

The test files were executed by pre-prepared tables containing fifty-nine letters and numbers and the thirty-one columns. The dotted groups of letters and numbers were reproduced by the participants in the tests, and their task were to find the data in the search and the markup table. In TEST 1, a number group was dictated, followed by a group of letters (37 AB, pause, 26 RTZ, pause, 31 XZ, etc.) at regular time intervals. The task of the tested students was to find the appropriate group in the table (AB 37, RTZ 26 ...) and mark it. In TEST 2, two groups of numbers with two lettering groups were dictated, e.g. 37 26 AB RTZ at regular intervals. The challenge was to combine the first pair of numbers with the first pair of letters and the second pair of numbers with the second set of letters. This means that in the test sheet, it was necessary to find and mark the AB 37 and RTZ 26 groups. In TEST 3, the test students were gradually dictated groups of numbers followed by a group of letters as in the TEST 1. Their task was to find the desired group again in the test file and here to indicate that if the number in the group was even, the group had to be marked with a circle. If the number in the group was odd, it was necessary to mark the group with a cross. In TEST 4, two groups of letters with two groups of letters were dictated to the students tested, their task being to combine the first group of numbers with the first group of letters and the second group of numbers with the second group of letters as in the second part of the test. In the task test group, the group was marked in the case of an even number by a circle, and in the case of an odd number by a cross. All TESTS 1-4 were evaluated for the mistakes in the test set of tasks, and the percentage success rate of each test subject (probands) was determined. Based on this, the overall order of individual candidates for participation in the experiment was determined - in the presurvey.

3. RESULTS AND DISCUSSION

Of the 100 candidates, 33 students were enrolled in the experiment, achieving a 60% success rate in the stress test. The goal of this experiment was to exclude those subjects who show increased emotional lability, low concentration ability and decreased ability to perform the multiple activities at the same time, at an increased load, which should ensure the greater uniformity of the sample while increasing the objectivity of the experimental results.

The experimental group of probands (33) consisted of the following:

- Pilot Group (7) PP-1;
- Air Traffic Control Group (13) PRLP-1, PRLP-2; and
- Group of Air Traffic Control Managers (13) RLD-1, RLD-2.

For the experiment, we used a device to measure the reaction time of probands. The reaction time meter serves to measure the reaction time of the selected subject. These devices are expanded around the world, especially in the armed forces, to the departments of general psychology, sports psychology, etc. Repeat time measurement devices can use simple tasks to measure the reaction time, such as Go / No Go tasks to investigate the higher brain centers, or more complex tasks to measure the critical reaction time to explore the cognitive processing capabilities.

The calling of aviation personnel is characterized by the fact that in real time they must simultaneously process acoustic commands and make movements in the manipulation and

pedipulation space. In this specific vocation, it is important to minimize the wrong decision at the required time. The choice of suitable adepts to pursue an aviation profession can be accomplished by testing of psychological readiness on the basis of reaction time measurement for the multitasking tasks.

The task of the student was to correctly respond to the 300 individual tasks randomly generated by the response time-measuring device. The critical point for entering the 300 correct answers was set to 600 seconds, and the 2-second partial condition was not respected for a single role.

After the TESTS 1-4, 25 students were also tested on the machine-tested visual light situations on 3 screens (MACHINE TEST), which had to be evaluated according to established rules. A total of 8 students did not participate in the machine testing.

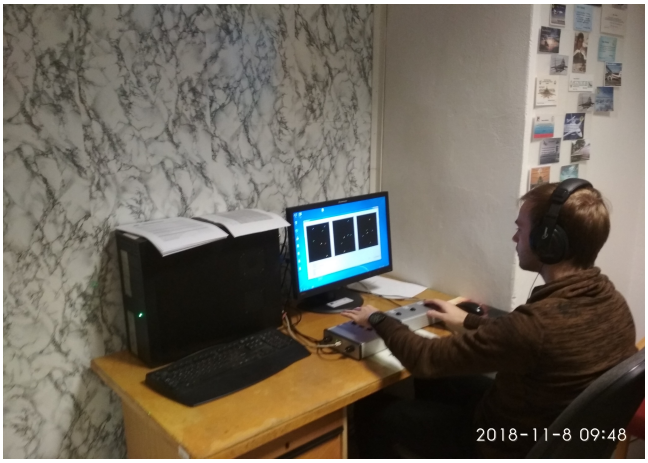

Fig. 1. Testing workplace

The key findings from the experiment were as follows:

- The number of four test sets of tasks with a break of 10 minutes between tests is appropriate to create a reasonable burden on the test persons.
- A time interval of approximately 2 seconds per 1 response produces a reasonable time pressure for the task solving.
- The second test set of tasks needs to be modified so that the tasks are not similar to the TEST 1, which allows the probands to have a relatively quick problem solving.
- Achieved results of the percentage success of the correct task responses were as a rule best in the TEST 1, and with increasing time, they deteriorated to the TEST 4; the worst outcome of the individual was the difference from the TEST 1 at 90% success rate of correct answers to the TEST 4 at 40% success rate of correct answers (Table 3, the student, line 18).
- The fastest time required to solve the tasks was 429 seconds, i.e. 1.43 seconds for the answer. The percentage success rate for the fastest student was 68.3%. Student with a limit of 600 seconds achieved a time of 587 seconds, with 71.6% of the problem solving success rate. The response speed does not always mean the right answer. It is of interest to prepare our students for the effective use of time to make their decisions within a set limit, or parts in the incomplete information conditions and rarely in the conditions of uncertainty.
- After completing the TEST 1 - TEST 4, 8 students no longer participated in the machine testing (MACHINE TEST) focused on the correct resolution of light situations in time pressure according to the established rules of assessment of the situation. The students were demotivated after demanding the test files of tasks and avoided the failure.
- MACHINE TEST with the simultaneous reception and counting of the sound signals during each light situation makes the decision process, reaction time and correctness of the decision considerably more difficult; it is a suitable complement to tests to increase the psychophysiological resistance of aviation personnel.

- MACHINE TEST allowed in one case to detect a color defect of the tested student who did not know clearly and correctly the location of the "red dot" in the different lighting situations, etc. In the case of a student who started preparing for the position of an air traffic controller, it was a negative result that significantly changed its routing in his life and change of study.
- The most important result of the experiment is the technical advice and SW tool that were completed.

Our results enable the individual assistance to the students to strengthen their psychophysiological resistance. The results allow the generalization of knowledge in favor of the aeronautical education system. The SW (technical device) used in "the MACHINE TEST", the Reaction Time Test, is subject to the European Patent Application.

Table 1

Experiment results - Average in testing (%)

A	B	C	D	E	F	G	H	I	J	K
Group	**Name**	**Surname**		**TEST 1**	**TEST 2**	**TEST 3**	**TEST 4**		**AVERAGE %**	
PP-1	J	K		96	100	90	93		94,75	
PP-1	R	K		96	100	86	83		91,25	
PRLP-1	J	L		96	100	76	93		91,25	
RLD-1	B	B		100	96	76	83		88,75	
RLD-1	L	B		100	100	63	86		87,25	
PRLP-2	Z	V		100	93	70	80		85,75	
RLD-1	M	S		100	93	76	66		83,75	
PP-1	D	B		96	89	66	80		82,75	
DLD-1	V	R		100	100	56	66		80,5	
PP-1	V	D		93	93	70	63		79,75	
PP-1	M	S		86	100	60	70		79	
PRLP-1	I	O		90	100	70	50		77,5	
RLD-1	M	T		90	96	50	73		77,25	
PRLP-1	G	C		90	100	46	70		76,5	
RLD-2	T	M		83	79	72	70		76	
PRLP-2	D	O		96	93	50	60		74,75	
PRLP-1	V	S		93	100	43	60		74	
PRLP-1	S	O		93	89	63	43		72	
RLD-1	M	P		80	96	46	63		71,25	
PRLP-1	P	G		93	82	70	40		71,25	
RLD-1	V	Š		83	90	53	53		69,75	
RLD-2	A	K		77	83	64	53		69,25	
PRLP-2	M	H		90	100	26	60		69	
PP-1	A	K		70	86	66	53		68,75	
RLD-1	V	B		96	93	30	53		68	
PRLP-1	M	L		93	96	40	43		68	
PRLP-1	L	Ž		86	96	43	46		67,75	
RLD-1	D	J		96	93	30	50		67,25	
RLD-1	P	K		93	96	20	46		63,75	
PP-1	D	S		70	86	56	43		63,75	
PRLP-1	J	E		90	79	40	40		62,25	
RLD-1	D	P		83	96	20	46		61,25	
PRLP-1	Z	P		66	93	50	36		61,25	

AVERAGE MACHINE TEST GROUPS +

The best result in the percentage averages was achieved at 95% of the correct workload solution. The worst result in the percentage of the average was 61.61% of the correct workload solution.

After the TESTS 1-4, 25 students were tested for the machine visual testing of the 3-screen (MACHINE TEST) light situations, which they had to evaluate according to the established rules. By default, a 2-second response time has been calculated. Within the set of 300 tasks, the limit was 600 seconds to complete the test. The minimum acceptable level was 600 seconds.

Table 2

Experiment results – Machine test

Group	Name	Surname	TEST 1	TEST 2	TEST 3	TEST 4	AVERAGE %	Machine Test
PRLP-1	M	L	93	96	40	43	68	429
PP-1	V	D	93	93	70	63	79,75	431
RLD-1	V	Š	83	90	53	53	69,75	431
PRLP-1	V	S	93	100	43	60	74	433
PRLP-1	S	O	93	89	63	43	72	451
PRLP-1	J	L	96	100	76	93	91,25	452
PRLP-1	P	G	93	82	70	40	71,25	472
PP-1	A	K	70	86	66	53	68,75	477
RLD-2	T	M	83	79	72	70	76	480
RLD-1	L	B	100	100	63	86	87,25	487
PP-1	D	B	96	89	66	80	82,75	487
PP-1	R	K	96	100	86	83	91,25	489
RLD-1	V	B	96	93	30	53	68	490
RLD-1	P	K	93	96	20	46	63,75	501
PRLP-1	G	C	90	100	46	70	76,5	507
PP-1	J	K	96	100	90	93	94,75	517
PP-1	D	S	70	86	56	43	63,75	536
PRLP-2	D	O	96	93	50	60	74,75	543
DLD-1	V	R	100	100	56	66	80,5	559
PRLP-2	M	H	90	100	26	60	69	564
PRLP-1	Z	P	66	93	50	36	61,25	569
PRLP-1	I	O	90	100	70	50	77,5	577
RLD-1	M	P	80	96	46	63	71,25	587
RLD-1	M	S	100	93	76	66	83,75	635
PRLP-1	L	Ž	86	96	43	46	67,75	890
RLD-1	B	B	100	96	76	83	88,75	
PRLP-2	Z	V	100	93	70	80	85,75	
PP-1	M	S	86	100	60	70	79	
RLD-1	M	T	90	96	50	73	77,25	
RLD-2	A	K	77	83	64	53	69,25	
RLD-1	D	J	96	93	30	50	67,25	
PRLP-1	J	E	90	79	40	40	62,25	
RLD-1	D	P	83	96	20	46	61,25	

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A total of 8 students did not participate in the machine testing. The fastest time required to solve the tasks was 429 seconds, i.e., 1.43 seconds for the answer. The percentage success rate for the fastest student was 68.3%. Student with a limit of 600 seconds achieved a time of 587 seconds, with a success rate of 71.6% for the problem solving.

The student (line 25) exceeded the maximum time limit and reached 635 seconds. The student (line 26) exceeded the maximum time limit and reached 890 seconds.

The results of the experimental group of all probands (33) are sorted by groups:

- Pilot Group (7) PP-1;
- Air Traffic Control Group (13) PRLP-1, PRLP-2; and
- Air Traffic Controllers Group (13) RLD-1, RLD-2.

They are expressed in Tab. 3.

4. CONCLUSIONS

Within the framework of experimental verification, the following key outputs were achieved:

- the final versions of 4 test sets of tasks in the field of measuring the psychophysiological performance of the candidates for aviation personnel have been established;
- MACHINE TESTS allowed in one case to detect a color identification failure of the tested student who did not know clearly and correctly identify the location of the "red dots" in the different lighting situations, etc. In the case of a student who started preparing for the position of an air

traffic controller, it was a negative result that significantly changed his life and the field of the study; the experiment and use of new SW to measure the selected factors of probands in solving the specific problems, under stress conditions, confirmed the potential to support the testing according to the medical requirements for aviation personnel;
- our results enable individual assistance to the students to strengthen their psychophysiological resistance;
- the new technical device and SW tool were designed, verified and finalized for the all testing processes of the candidates for aviation personnel;
- based on experimental verification, the new technical device and the SW tool were registered for the patent protection of copyright; the patent process is still ongoing.

The main aim of the experiment, a preliminary survey, was to verify and prepare a final version of the test sets of tasks in the field of measuring the psychophysiological performance of aviation personnel candidates and to complete the creation of a technical device and software tool for these processes. The primary goal of the experiment was met.

The technical device and the SW used in the experiment to measure the reaction time for the multitasking missions etc. are the subjects of the patent application. The technical device and the SW are specific and able to identify the acoustic sensations, the movements in handling of device, and in the pedipulation space at the same time. Once a critical point has been reached, it is possible to determine the readiness for the performance of a specific professions (e.g. Aviation Personnel). More information about the technical equipment and the SW tool will be provided to the readers when the patent process is completed.

The terminology used in the experiment complies with the national standards and with applicable international standards based on the regulations of ICAO, EASA, FAA, Eurocontrol, etc.

The methodology used is not new, but the added value of the experiment is in its update for the students as candidates for aviation professions, as well as in the digitization and visualization of measurements with the new technical and software support. The innovativeness of the results lies in the adaptation and extension of the methodology for the selection of students - aeronautical staff for the environment of the aeronautical educational institution.

The results represent the scientific value at the national level. We respect the experience of the international community as well as the knowledge at the national levels to improve the aviation personnel selection processes and the individual assistance and advice to the candidates of aviation personnel. The national experience has the potential to support the validated methodologies of international organizations and to contribute to a more inclusive knowledge of the aviation candidate as well as in the ongoing evaluation of the psychophysiological parameters of the aviation personnel. The use of new technical equipment and software can be seen mainly in the practice of aviation medicine in the Military Aviation Hospital in Košice in the selection process of aviation personnel as well as in other interested parties.

The proposal of new technical equipment and the SW tool for digitization, visualization and objective evaluation of selected psychophysiological performance according to the updated methodology represents a modern didactic means for improving the quality of the selection process and at the same time as a sophisticated didactic device within the aviation education as a didactic system.

The experiences from the experiment and from the research project supported by a grant from the Agency for Science and Research of the Slovak Republic will be used to improve the education process at the Faculty of Aeronautics of the Technical University in Košice as well as to exchange the experience in the internationalization of aviation education and research with our partners both at home and abroad.

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Table 3

Experiment results – Groups results

A	B	C	D	E	F	G	H	I	J	K
Groups	**Name**	**Surname**		**TEST 1**	**TEST 2**	**TEST 3**	**TEST 4**		**AVERAGE %**	
PP-1	V	D		93	93	70	63		79,75	
PP-1	A	K		70	86	66	53		68,75	
PP-1	D	B		96	89	66	80		82,75	
PP-1	R	K		96	100	86	83		91,25	
PP-1	J	K		96	100	90	93		94,75	
PP-1	D	S		70	86	56	43		63,75	
PP-1	M	S		86	100	60	70		79	
PRLP-1	M	L		93	96	40	43		68	
PRLP-1	V	S		93	100	43	60		74	
PRLP-1	S	O		93	89	63	43		72	
PRLP-1	J	L		96	100	76	93		91,25	
PRLP-1	P	G		93	82	70	40		71,25	
PRLP-1	G	C		90	100	46	70		76,5	
PRLP-1	Z	P		66	93	50	36		61,25	
PRLP-1	I	O		90	100	70	50		77,5	
PRLP-1	L	Ž		86	96	43	46		67,75	
PRLP-1	J	E		90	79	40	40		62,25	
PRLP-2	D	O		96	93	50	60		74,75	
PRLP-2	M	H		90	100	26	60		69	
PRLP-2	Z	V		100	93	70	80		85,75	
RLD-1	V	R		100	100	56	66		80,5	
RLD-1	V	Š		83	90	53	53		69,75	
RLD-1	L	B		100	100	63	86		87,25	
RLD-1	V	B		96	93	30	53		68	
RLD-1	P	K		93	96	20	46		63,75	
RLD-1	M	P		80	96	46	63		71,25	
RLD-1	M	S		100	93	76	66		83,75	
RLD-1	B	B		100	96	76	83		88,75	
RLD-1	M	T		90	96	50	73		77,25	
RLD-1	D	J		96	93	30	50		67,25	
RLD-1	D	P		83	96	20	46		61,25	
RLD-2	T	M		83	79	72	70		76	
RLD-2	A	K		77	83	64	53		69,25	

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