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CASE STUDY OF THE PSYCHOPHYSICAL STATE OF STUDENT-OPERATORS DURING UAVO TRAINING, BASED ON HEART RATE PARAMETER

Stan psychofizyczny uczniów-operatorów w trakcie szkolenia UAVO, na podstawie parametru tętna. Studium przypadku

Abstract: *This article focuses on the human factor in UAV operations. In the manuscript, research on the psychophysical state of student-operators under the license of UAVO VLOS <4 kg. For the analysis of the psychophysical state, the pulse parameter was used, which is one of the values that describe the work of the cardiovascular system and is one for the objective methods of assessing the psychophysical state of a human being. The data collected were analyzed using the STATISTICA software. The article focuses on the above aspect and analyzes the psychophysical state of the student-operator during flight training. The obtained results were also related to research on similar topics in the chapter discussion section.*
Keywords: UAV operator, psychophysical state, heart rate

Streszczenie: *Artykuł koncentruje się na czynniku ludzkim w operacjach UAV. Przeprowadzono badania stanu psychofizycznego studentów-operatorów na licencji UAVO VLOS <4 kg. Do analizy stanu psychofizycznego wykorzystano parametr tętna, który jest jedną z obiektywnych metod oceny stanu psychofizycznego człowieka. Zebrane dane analizowano za pomocą oprogramowania STATISTICA. Skupiono się na pracy układu sercowo-naczyniowego i przeanalizowano stan psychofizyczny ucznia-operatora podczas szkolenia w locie. Uzyskane wyniki odniesiono również do badań o podobnej tematyce w rozdziale dyskusyjnym.*
Słowa kluczowe: operator BSP, stan psychofizyczny, tętno

1. Introduction

Aviation is one of the fastest growing modes of transport. Together with significant technological development in the world, the popularity of unmanned aerial systems is increasing. Unmanned aerial vehicles (UAV) allow virtually everyone to use them for recreational or commercial purposes. In Poland, in recent years, there has been a significant increase in the number of certificated qualifications issued for operators of unmanned aerial vehicles by approximately 50% annually [4,5]. This applies in particular to the qualification certificate allowing the piloting of UAVs in sight, with aircraft weighing less than 4 kg. Due to the growing popularity of this type of devices, an increase in the number of incidents in which UAVs are involved can also be observed [6,7]. Furthermore, flight safety is a vital issue in the air transport system [9]. The human factor is a very important aspect when operating a UAV in commercial or recreational conditions. According to the analysis of the literature, it is known that humans are the cause of about 70% - 80% of all aviation incidents around the world [2,16,12]. The occurrence of events related to the human factor may be significantly influenced by the level of task load in a given operator. The workload experienced by the operator is the sum of many individual factors (such as the level of skill, experience, or strategies used) and the objective requirements imposed by the task itself [11,17]. Analyzes concerning the human factor contained in the literature focus mainly on the line pilot error, which is directly related to Commercial Air Transport (CAT). It is also worth paying attention to the error of the pilot/operator in flights with unmanned aerial systems, so that on the basis of analyzes, it is possible to reduce the risk of occurrence of air incidents involving them. The errors that occur during UAV piloting can be significantly influenced by the course of training, especially its practical part. Training is a key element in learning to operate a UAV and perceiving the safety of air operations.

In connection with the above, the article decided to focus on the psychophysical condition of the student-operator during the practical training for the qualification certificate entitling him to pilot a UAV weighing up to 4 kg, in sight, in accordance with the NST01 scenario.

As part of the article, it was decided to analyze the basic parameter that characterizes the work of the cardiovascular system, which is the heart rate (HR). According to sources from the literature, one of the methods that best describes the psychophysical state of a human being are methods based on the analysis of the work of the cardiovascular system [21,3,20]. Furthermore, research results have shown that heart rate levels differ significantly between tasks characterized by low and high levels of workload [3]. This parameter is also a promising physiological correlate of cognitive functioning and heart rate is considered an index of autonomic control of the heart [10].

2. Research Methodology

Research was focused on the training area for UAVO. The training process and the obtaining of the VLOS <4 kg qualification certificate were carried out according to the regulations of the European Union [8]. The research group consisted from 11 subjects of various age groups (between 23 and 45 years old, and one person was about 70 years old). The subjects were volunteers who gave their oral consent to the study and were informed of its purpose. Research was carried out in January 2021 and was carried out during practical training. Each person in the research group had no previous aviation experience.

To adequately characterize the research group, a questionnaire survey was conducted before the participants started training. It concerned the age of the respondents, the subjective assessment of the speed of reaction, the assessment of their own cognitive abilities, the ability to use a gamepad or using various simulator games every day. As a result of the analysis, the following results were obtained:

- none of the respondents has an aviation license or a certificate of qualifications,
- 1 person plays RPG computer games (every day),
- none of the respondents uses flight / driving simulators on a daily basis,
- half of the respondents rate their reaction speed as good, 1 person average and one person very good,
- everyone in the research group defined their cognitive abilities as good or very good,
- one of the interviewees believes that she is not nervous, two that it "happens" and one person thinks he is very often nervous,
- all respondents described their attitude as highly motivated to obtain a license.

Each of the respondents underwent theoretical and practical training, consisting of the elements presented in Table 1.

Table 1

Elements of theoretical and practical training in UAVO VLOS (own elaboration)

THEORETICAL PART	PRACTICAL PART
1. Aviation law: rules on obtaining an operator's certificate of qualification (UAVO), air traffic regulations and procedures, air traffic services and authorities, airspace classification, consequences of airspace violation. 2. Rules for flying in sight (VLOS). 3. Man as an operator of an unmanned aerial vehicle. 4. Flight safety and dangerous situations. 5. Operation, construction, and operation of systems, components of the unmanned aircraft, and the principles of performing unmanned aircraft flights.	1. Preparation for the flight of the unmanned aircraft. 2. Safe performance of aviation activities. 3. Ground handling and airworthiness review. 4. Perform normal pilot procedures and those applicable to hazardous and emergency situations.

The research was carried out during the practical training of each person in the research group. Practical training included 4 flight hours at Poznan-Kobylnica Airport (EPPK). The exercises were carried out in a specially prepared area, consisting of a helipad used for take-offs and landings and four poles delineating the training field and the moments and places of individual maneuvers. Training was divided into two days. During the training, maneuvers such as:

- fly horizontally along the contour of a square, hovering over each stick,
- flight in a UAV along the contour of a square. UAV in the direction of flight, overhangs at corners when turning,
- flights on a square contour with a change in the UAV direction.

Each maneuver was trained in the GPS and ATI functions. DJI Phantom 3 Advanced v2 was used to perform the training exercises. These UAVs weigh 1280 g and can ascent 5 m/s. It can operate at a temperature of -10 to 40ºC and the maximum flight time (in full batteries) is about 23 min. These UAVs are providing a fail safe system in case of lost signal or the low battery device can return to the established place and land. The POLAR H10 belt was used to measure the work of the cardiovascular system. It is a sensor that measures with two electrodes. The device parameters measures continuously such parameters as heart rate, delta RR, RR interval. Measurements focus on the heart rate value. The measurement device was chosen for its simplicity and ease of use. It is a noninvasive device that did not interfere in any way with the functioning of the research subject during training. It is also easy to use, which reduces the risk of measurement failure. Every day, the examiner put on the test equipment one hour before the start of the training and removed it one hour after its completion. In this way, a sample was obtained concerning the resting heart rate (reference measurement) in the research group. An application dedicated to the manufacturer was used to process the measurement results. The MS Office Excel and STATISTICA programs were used for data analysis.

3. Research result

For each student-operator, data on the resting measurement and the measurement made during the practical training were collected. On the basis of the results, tests of the normality of distributions were carried out. None of the heart rate waveforms was normally distributed. Subsequently, it was decided to perform the significance of the differences to check whether all subjects achieved significant differences in heart rate between rest and comparative measurement. Due to the lack of normality of the distribution, a nonparametric Wilcoxon pair significance test was performed. Furthermore, standard deviations were calculated for each student-operator for the measurement at rest (SD) and for practical training (SD *). Based on the data analysis (Table 2), it was decided not to include the student operator number 6 in future analyzes, as no significant differences were found between the resting and comparative measurements. Furthermore, 45% of the respondents achieved lower standard deviations during practical training.

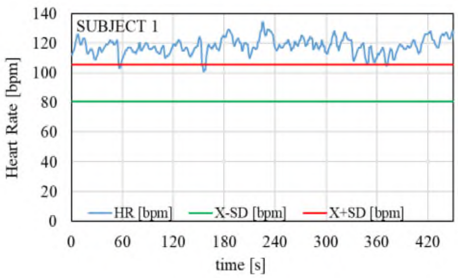
Table 2

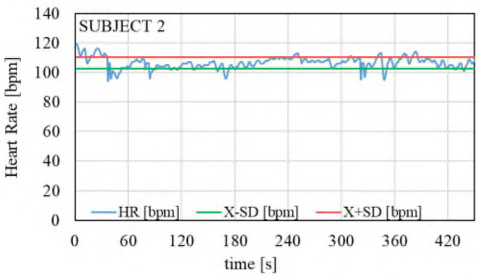
Results of statistical analysis heart rate variable for each subject tested (own formulation)

Student-operator	p-value	revelance	$\bar{X}$HR	$\bar{X}$HR*	SD	SD*
Subject 1	0	p<0.05	92.991	118.024	**12.442**	**5.353**
Subject 2	0.0438	p<0.05	106.514	107.338	3.885	5.017
Subject 3	0	p<0.05	75.924	89.695	**3.895**	**3.446**
Subject 4	0	p<0.05	89.320	97.607	11.984	13.492
Subject 5	0	p<0.05	101.075	78.409	**15.935**	**6.056**
Subject 6	**0.169**	**p>0.05**	**85.965**	**86.541**	**5.439**	**2.638**
Subject 7	0	p<0.05	89.720	111.344	**10.639**	**6.177**
Subject 8	0.000081	p<0.05	101.165	99.600	5.040	6.708
Subject 9	0	p<0.05	91.478	99.501	5.030	7.179
Subject 10	0	p<0.05	97.051	107.091	3.299	5.211
Subject 11	0	p<0.05	95.934	99.678	3.771	4.678

SD – standard deviation value for the comparative measurement
SD* – standard deviation value for practical training
$\bar{X}$HR – heart rate average value for the rerefernce measurement
$\bar{X}$HR* – heart rate average value for comparative measurement

This means that their heart rate during training was less variable and fluctuated around similar values during flight training than during rest. Figure 1 shows the pulse course during the practical training for individual subjects. Part of the heart rate variable waveform (7 minutes) is presented, because cardiovascular tests can be analyzed in terms of long-term or short-term variability. The measurements taken were not 24-hour samples; therefore, the analyzed results are related to the short-term variability aspect. At the same time, with short-term variability, the analyzed measurements usually last about 5 minutes. The sample length was chosen as 7 minutes because this was usually the time it took to repeat the exercise. The samples presented constitute the second attempt of the exercise, which consisted of moving the unmanned aerial vehicle in a square, from pillar to pillar, with a rotation of a 90^0 UAV over each of them.





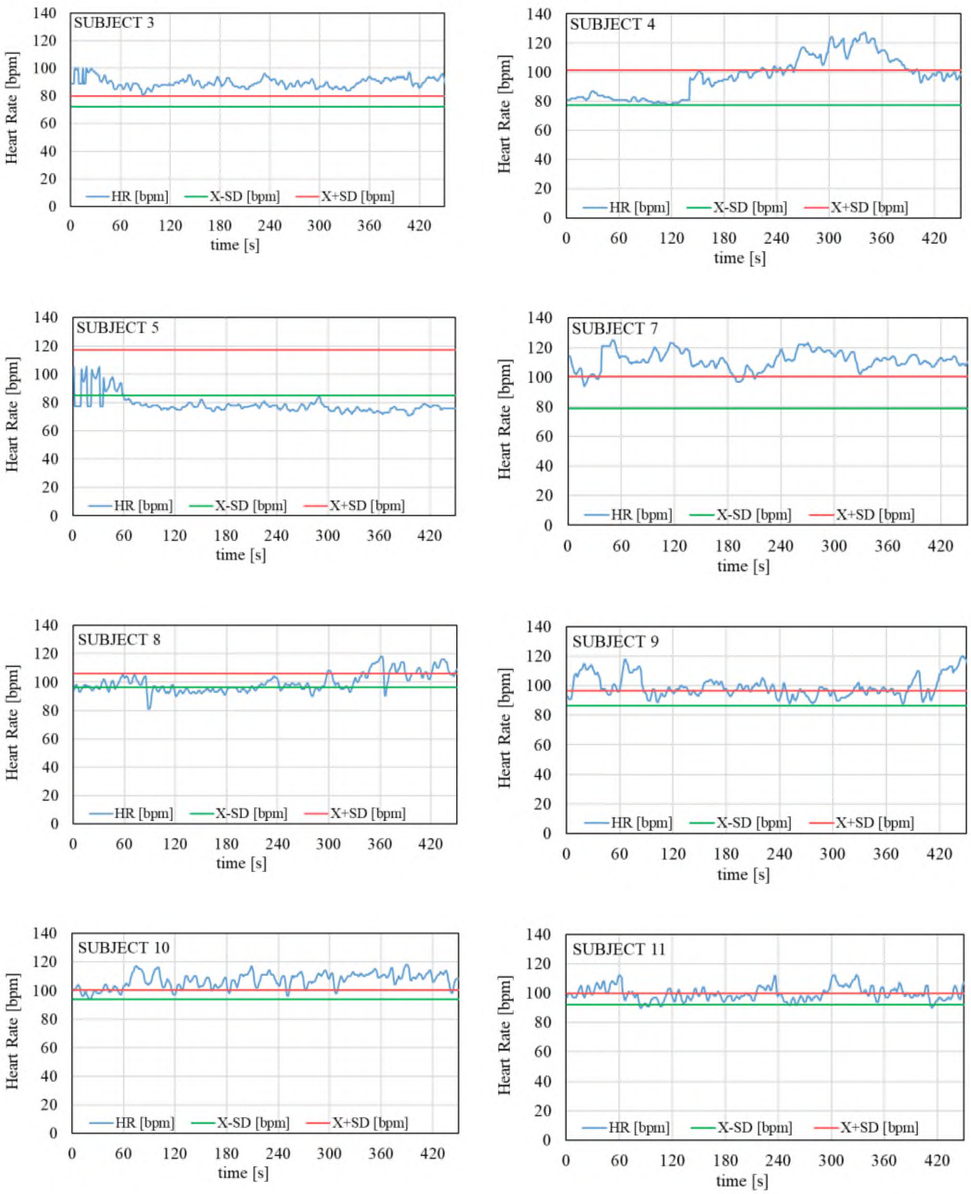


Fig. 1. Results of the research for each subject tested. The blue line marked the heart rate course in the 7 minute interval, and the red and green lines marked the interval between average + or – standard deviation for reference measurement (own elaboration).

When analyzing the graphs presented, it can be seen that 70% of the respondents, while exercising, achieved values significantly different from those obtained while resting. In the case of student operators number 1, 3, 7 and 10 (40%), it can be noticed higher heart rate values lasting throughout the entire exercise. This may mean that the subjects felt nervous due to the difficulty in performing the exercise, which resulted in an increase in heart rate. During exercise, the respondents stood in one place, eliminating movement as a factor that can affect higher heart rate values. This means a significant workload for these people. Subjects 9 and 4 (20%) showed values significantly different from those at rest only for very short periods of time. These are the maximum time intervals of one minute when a significant increase in heart rate can be observed. This is most likely due to an error that occurred during the exercise or a sudden loss of orientation regarding the position of the front of the UAV. One of the student operators (subject 5), during the exercise, had heart rate values lower than those obtained during the resting measurement. It may indicate a measurement error or mean that the participant did not care about proper performance of the exercise or that it was not difficult for him.

4. Discussion

Research related to the psychophysical state of operators in M-T-E systems (man-technology-environment) is an important aspect of understanding human activities and reducing the risk of threats. They focus mainly on objective methods, such as the work of the cardiovascular system. Research on unmanned aerial systems carried out in recent years has mainly focused on the development of technology and air traffic control of this type of aircraft [24]. The safety aspect of the operations of unmanned aerial vehicles is mainly related to risk management models [23]. Taking into account the impact of the human factor on the safety of air operations, it is also worth paying attention to the pilot/operator error in the context of unmanned aerial vehicle operations. In the literature on this subject, studies on task load and psychophysical state are mainly focused on pilots [13-16,1,18] and air traffic control operators [22]. These studies also often deal with errors resulting from cooperation between flight crews [19]. However, there are no studies on the psychophysical condition and the burden on operators of unmanned aerial vehicles. The article focuses on the above aspect and analyzes the psychophysical state of the student-operator during flight training.

The obtained results are consistent with the information contained in the scientific literature: with an increase in the task load, the human heart rate will increase. This phrase was confirmed by 72% of respondents in the group. In addition, the normal heart rate range for an adult is 60 to 90 bpm. As can be seen from the results, also 72% of the respondents obtained higher heart rate values while performing the training exercises, when the student-operators were only standing and rarely walked. This means that higher heart rate results are most likely caused by nervousness or stress from difficulty in completing a task, and fatigue. Furthermore, 45% of the respondents achieved lower standard deviations during practical training. This means that their heart rate during training was less variable and fluctuated around similar values during flight training than during rest. This means that their heart rate during training for a long time fluctuated around high values and did not change rapidly from lower to higher values.

The limitations of the study carried out depend mainly on the number of the research groups. In order to carry out a more detailed statistical analysis, a research group should be gathered, consisting of at least 20 respondents. Furthermore, the research was carried out under unfavorable weather conditions, because it was a winter month, not conducive to spending several hours outside. Additional factors influencing the results of the conducted research could be the continuous presence of the instructor, which could also affect the feeling of stress and nervousness during training exercises and the use of expensive training equipment, such as UAV.

Research in real conditions, carried out on student-operators, was selected due to the fact that training is the first stage of the path to independent flying, and taking into account the psychophysical state of students may have a positive impact on the effectiveness of teaching, which is also associated with reducing the risk of threats in air operations.

5. Conclusions

The article discusses the psychophysical condition of student operators during flight training, allowing them to perform UAV operations weighing up to 4 kg, in sight, according to the NST01 scenario. For the analysis of the psychophysical state, the heart rate parameter was used, which is one of the values that describe the work of the cardiovascular system and is one of the objective methods of assessing the psychophysical state of a human being. Based on the tests and analyzes, the following conclusions can be obtained:

- significant differences were found between the resting heart rate and the heart rate obtained there during the practical training in all student-operators,
- based on the resting measurement, it was possible to determine normal heart rate ranges, individual for each student-operator,
- 72% of the respondents achieved significant differences in heart rate value compared to individual ranges,
- 40% of the student operators achieved heart rate values much higher than the set range during the entire exercise,
- the heart rate value may differentiate the psychophysical state of operators during flight training.

The psychophysical state of the UAV operator is a very important concept, especially in terms of flying training. Adding psychophysical analysis as an element of training can lead to an improved assessment of the student-operator. It can lead to a more accurate identification of problematic tasks, which will result in greater training effectiveness. However, the whole process can significantly reduce the risk of threats in aspects of human factor in UAV flights.

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