



Scientific quarterly journal ISSN 1429-7264

**Agricultural Engineering**

2014: 4(152):111-121

Homepage: <http://ir.ptir.org>



DOI: <http://dx.medra.org/10.14654/ir.2014.152.086>

## IMPACT OF THE MENTAL ACTIVITY TYPE ON THE MENTAL FATIGUE AND DEGREE OF PHYSIOLOGICAL WORKLOAD<sup>1</sup>

Paweł Kielbasa\*, Tadeusz Juliszewski, Justyna Rusnak, Krzysztof Pikul

Institute of Machinery Management, Ergonomics and Production Processes  
University of Agriculture in Krakow

\*Contact details: ul. Balicka 116B, 30-149 Kraków, e-mail: [pawel.kielbasa@ur.krakow.pl](mailto:pawel.kielbasa@ur.krakow.pl)

### ARTICLE INFO

#### Article history:

Received: October 2014

Received in the revised form:

November 2014

Accepted: December 2014

#### Keywords:

mental fatigue

ergonomic

rate

intellectual work

### ABSTRACT

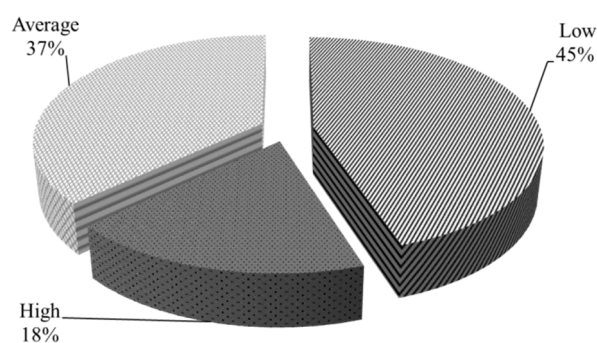
The paper is an attempt to determine mutual relations between the length and type of activity related to intellectual work and the degree of mental fatigue and the heart rate reserve. The tests were carried out on the group of 25 persons, who through realization of particular training stages concerning operation of modern farm tractors through special logical tests and measurement of the heart rate generated information on the mental fatigue and stress during the experiment. It was found out that along with the increase of the duration of intellectual work, the time necessary for accomplishing a logical task and number of mistakes increases. It was also reported that with each test of a similar logical structure, the stress factor decreased and the process of learning took place in case of learning persons. Thus, during the last measurement, the investigated group obtained relatively better results than in the previous test.

## Introduction

Work is a significant factor of human development and an organizing element which consumes approx. 66% of the adult life (Wróblewska, 2004). Traditionally, two types of work are distinguished. The first one is the work of muscles – occupational physiology deals with this issue and the intellectual work – defined by the occupational psychology (Olszewski, 1997). The intellectual work focuses on taking decisions based on external information (exteroceptive) and internal (prioceptive). Thus, in the analysis of the human-work system, the intellectual work focuses on the first two stages of the process: reception of information and its processing and decision taking. Whereas the third stage – performing an activity- is an element of mainly physical work (Olszewski, 1997). The trend in favour of increasing the role of the intellectual load and in consequence the impact on the production process also relates to widely understood agriculture, where the degree of technical and technological complexity forces out automation and robotization of activities and human roles comes down to the operator- programmer role.

<sup>1</sup> The paper was written as a part of the statutory research

Awareness of the effects of undertaking an improper decision intensifies stress increasing the burdening of the nervous system. The degree of the aptitude for learning how to operate technical means by operators with the use of the user's manual becomes very important and influences directly the safety and efficiency of work (Juliszewski et al., 2013). No compatibility of interfaces of machines which carry out the same technological function intensifies the mental fatigue and in consequence possibility of making a mistake. Juliszewski et al. (2010; 2012) tested a number of computer onboard interfaces of machines and farm tractors and procedures of starting the selected functions observing many times the lack of logical relations between them in tractors and machines of other makes. According to Złowodzki et al. (2011) loading with information results not only from its amount but also from the necessity of knowing many sequences and proper information decoding. An algorithm for operating various machines and thus other various signalling devices by relatively short time during a year is a specific feature of work in agriculture (Juliszewski, 2008a). Technical progress caused intensification of agricultural work and increase of the degree of complexity of agricultural machines and devices. The problem of operation and supervision of the units operation appeared, which is related to the necessity of having proper knowledge and qualifications by farmers. Research proved that farmers with a high stress index were more accident-prone by 65% more than farmers, who were more stress-resistant (fig.1). It was also proved, that such stressful events as farm debts, financial problems influence the increase in the accident rate (Cież, 2008).



source; PIP (2013)

Figure 1. The level of stress causing factor of work in agriculture

Estimations show that every four employee in the European Union experiences intellectual workload and 50-60% of sick absenteeism is related therewith. Stress is at the second position (after muscular and skeleton ailments) among the most often health problems related to professional work (PIP, 2012). As a part of operations included in the programme, a PIP inspector [Polish State Work Inspection Office] evaluated stress causing properties of work in 289 establishments for the total number of 1012 various work stations. It was found out that 40% of stations is burdened with low level of stress causing features of work, also 40% with the average level of stress causing factor and 20% with high (PIP, 2007).

## **Objective, scope and methodology of work**

The objective of the paper was to determine the impact of the length and type of activity related to intellectual work on the mental tiredness of a man and their relationship with the heart rate reserve. The scope of work included the tests on the mental fatigue with the mathematical tests and physical load method with the use of HRR. The experiment was carried out on the group of 25 people with similar intellectual abilities and the degree of knowledge advancement in the scope of technique and technology applied in agriculture. In order to force out mental fatigue, user's manuals for Fendt factors 930 Vario and John Deere series 8320 were used. They were being read (analysed) by the tested people for 30 minutes and then they answered control questions which verified the degree of knowledge on the operation of the said tractors. This cycle was repeated three times. Initially the questions concerned the basic functions of controlling tractors and then practical identification of sub-assemblies and procedures, with which they were acquainted during the analysis of the user's manual.

Before the experiment the tested persons solved logical tasks with the use of the "tester" program (Juliszewski, 2008b). The test assumes that the number of mistakes and the duration of the test are related to the level of the mental fatigue: the bigger fatigue the higher number of mistakes and the longer time of calculations. The test consists of 50 calculations of differences from randomly generated numbers or figures. The result of operations is also a one-figure value (from 0 to 9), which is introduced to the computer with the use of a numeric keypad. The number of tasks was 50 and the time interval was not limited, at the same time the number of heart contractions of particular persons was measured with the use of the following measuring devices: POLAR S-810<sup>TM</sup> and Omron M3 manometer. Then, the heart rate reserve index was calculated (Groborz et al., 2005) defining the degree of physiological load with the use of Buchberger scale (1984). The measurement of the above-mentioned value was carried out four times i.e.:

- a standard measurement was carried out before the experiment in order to determine the reference point for relative measurements and to determine variability of experimental population on account of the tested properties,
- the measurement after the first stage of fatigue was carried out after the experimental population had read the selected fragments of the user's manual and answered questions checking their knowledge,
- the measurement after the second stage of fatigue was carried out after practical realization of identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual.
- the measurement after the third stage of fatigue carried out after the problem task on the analysis of the user's manual was accomplished.

## **Research results**

In case of the first measurement (standard measurement) which constitutes the output data base, which were considered as the standard data, it was found out that the average time necessary to provide an answer (fig.2) was 1.87 seconds and characterized with a high coefficient of variation which was approx. 64%. High variation could have resulted from varied skills of the tested persons in functioning in the stressful situation, but it could not have resulted from a varied level of education.

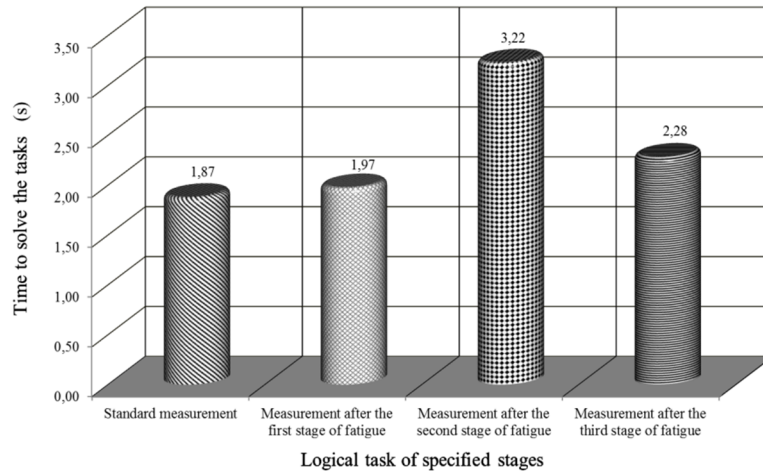


Figure 2. Time necessary to accomplish a single logical task at particular stages of the experiment

When analysing the time spent on accomplishing a single logical task after the first stage of the experiment, i.e.: "the experimental population had acquainted with the selected fragments of the user's manual and took the test" it was determined that the time necessary to take the logical test was not extended. Answering a single logical task in case of the measurement carried out after the second stage of fatigue was the longest and it was as much as 3.2 seconds (fig. 2), i.e. "carried out after a practical identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual, assessed with points". It should be emphasised that it was 1.72 times longer than the time necessary to accomplish a single logical task in case of the standard measurement. When analysing the last measurement (attempt after the third stage of fatigue), it was determined that the time necessary to accomplish a single logical task was 0.94 seconds lower in comparison to the time reported after the second stage of fatigue and it was 2.28 seconds. One should pay attention to the high coefficient of variation, which in case of the measurement after the third stage of fatigue was over 67%, which proves a considerable individualization of the level of fatigue within the experimental group. Information stating that despite a long time of mental fatigue, the time necessary to accomplish a logical task was relatively shorter, which seems to be alogical, should not be omitted. However, taking into consideration that ability to accomplish specific type of logical tasks could be learned and accustoming the experimental population to a given procedure, the obtained result may be assumed as correct. Figure 3 presents the scope of variation of the time of answering particular logical questions.

In order to determine statistically significant difference between the length of time for accomplishing a single logical task after listed stages of the experiment the analysis of variance with the test of differences significance was carried out (table 1).

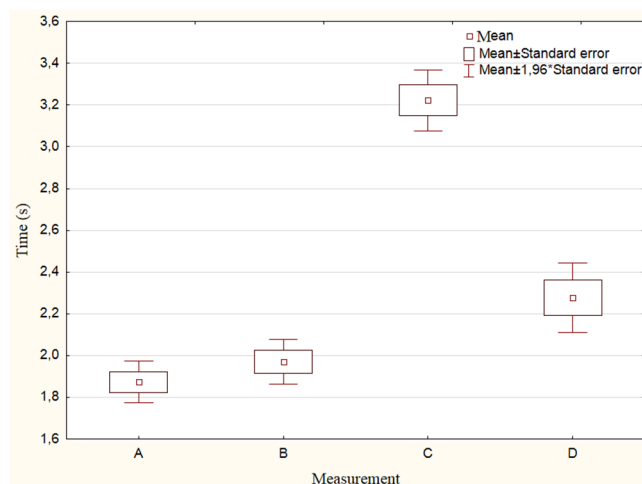


Figure 3. Diversification of the time required to accomplish a single logical task including a standard mean error

Table 1

The results of Tukey's test for testing statistical significance of differences in the time required for accomplishing a single logical task between particular stages of mental fatigue

Stages of experiment	A	B	C	D
Standard measurement (A)	X	X	X	X
Measurement after the first stage of fatigue (B)	---	X	X	X
Measurement after the second stage of fatigue (C)	*	*	X	X
Measurement after the third stage of fatigue (C)	*	*	*	X

\* statistically significant difference

--- - no differences

As much as 5 statistically significant differences in the mean values of the analysed parameter out of six possible were reported. No statistically significant differences were reported (table 1) only between the time needed to give an answer in case of the standard sample "A" and the test carried out after the first stage of fatigue "B". No difference may result from a small initial fatigue.

In case of the standard measurement, which constituted the output data base, it was reported that average frequency of heart contractions during the test was  $71.6 \text{ ud}\cdot\text{min}^{-1}$  at low, because only 11.6% coefficient of variation. The highest value of rate, namely  $81.3 \text{ ud}\cdot\text{min}^{-1}$  was reported after the first stage of fatigue "B" (fig. 4) i.e. after the part checking the group's participants' knowledge on sub-assemblies and procedures included in the analysed user's manuals of tractors. It should be emphasised that the the difference of the reported rate values in comparison to the standard measurement was  $9.7 \text{ ud}\cdot\text{min}^{-1}$ .

Increase in the frequency of heart contractions after the first stage of fatigue may be justified with a stress causing factor, namely the test. When analysing the following heart rate measurements, that is after the second and the third stage of fatigue (measurements "C" and

"D") a downward trend of the heart rate during the test (logical one) was reported. It should be mentioned that the next stages of the experiment were more practical in nature and the logical test does not constitute a novelty, which could have resulted in the decrease of the stress causing factor. Thus, a relative normalization of the frequency of heart contractions was reported. Despite this, the heart rate value in the "C" and "D" measurement was at the level which was higher than in case of the standard measurement and after the third stage of fatigue it was  $75.4 \text{ ud}\cdot\text{min}^{-1}$ . Figure 5 presents the scope of the variability of heart contractions during the test at particular stages of the experiment.

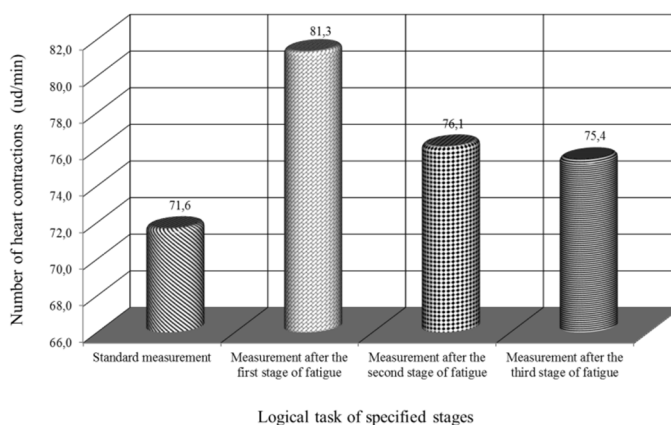


Figure 4. Number of heart contractions during the test at particular stages of experiment

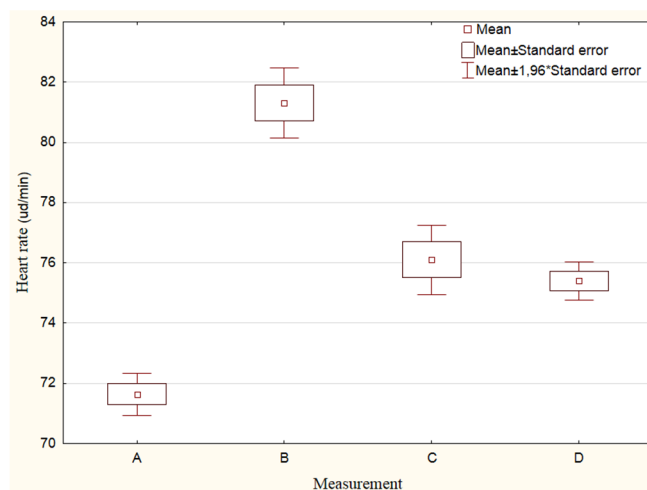


Figure 5. Diversification of the number of heart contractions during the test including the standard mean error

As much as 5 statistically significant differences in the mean values of the analysed parameter out of six possible were reported (table 2). No statistically significant differences were reported only between the number of heart rate contractions in case of the test after the second stage of fatigue "C" and the test carried out after the third stage of fatigue "D".

Table 2

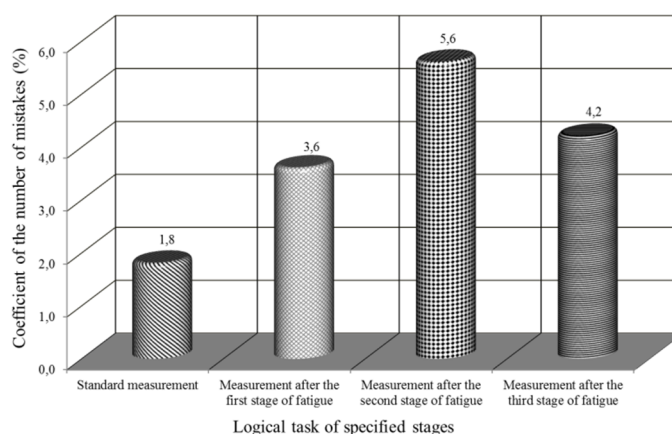
*The results of Tukey's test for testing statistical significance of differences of the number of heart contractions between particular stages of mental fatigue*

Stages of experiment	A	B	C	D
Standard measurement (A)	X	X	X	X
Measurement after the first stage of fatigue (B)	*	X	X	X
Measurement after the second stage of fatigue (C)	*	*	X	X
Measurement after the third stage of fatigue (D)	*	*	----	X

\* statistically significant difference

--- no differences

When analysing the number of mistakes made in the logical test, it was reported that in case of the first measurement (standard measurement) a percentage coefficient of the number of mistakes in the logical test (fig.6) was 1.8%.



*Figure 6. Percentage coefficient of the number of mistakes made in the logical test at particular stages of the experiment*

The highest number of mistakes, which was 5.6% was registered in case of the measurement after the second stage of fatigue "C" that is after the part concerning the identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual. It was determined that the value reported in the "C" test is over three times higher than the value reported in the standard test. After the analysis of the results of the last test "D" (measurement after the third stage of fatigue) it was determined that the number of mistakes was 4.2% and was by 1.4% lower than the number of mistakes made in the logi-

cal test taken after the second stage of fatigue. When observing the trend of the number of mistakes made in the logical test, one may notice, that their number increased at the stages "A", "B", "C" which is justified with the growing mental fatigue, whereas it decreases at the stage of the "D" measurement. Growing mental load should generate the highest level of mistakes in the test, which was obtained after the third stage of fatigue. However, taking into consideration that ability to accomplish specific type of logical tasks could be learned and accustoming the experimental group with a procedure, the obtained result may be assumed as correct. Figure 7 presents the scope of the variability of the number of mistakes made in the logical test.

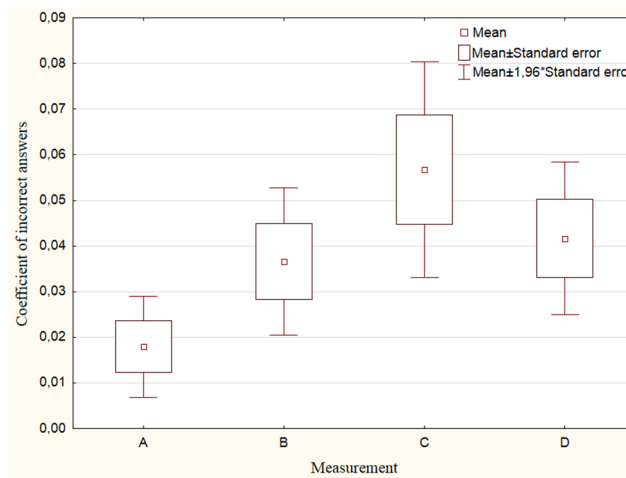


Figure 7. Variability of the number of mistakes in the logical test including the standard mean error

Only one statistically significant difference in the mean values of the analysed parameter out of six possible was reported (table 3). This difference appeared between the number of mistakes made in the standard sample "A" and the sample carried out after the second stage of fatigue. In the remaining cases no statistically significant differences were reported.

Table 3

The results of Tukey's test for testing statistical significance of differences of the mistakes made in the logical test between particular stages of mental fatigue

Stages of experiment	A	B	C	D
Standard measurement (A)	X	X	X	X
Measurement after the first stage of fatigue (B)	----	X	X	X
Measurement after the second stage of fatigue (C)	*	----	X	X
Measurement after the third stage of fatigue (C)	----	----	----	X

\* statistically significant difference

--- - no differences



In case of the index of using the heart rate reserve in the first measurement "A", which constitutes the output data base considered as standard, it was reported that the index of using the heart rate reserve (fig. 8) was 11.6% at the coefficient of variation which was 50.8%.

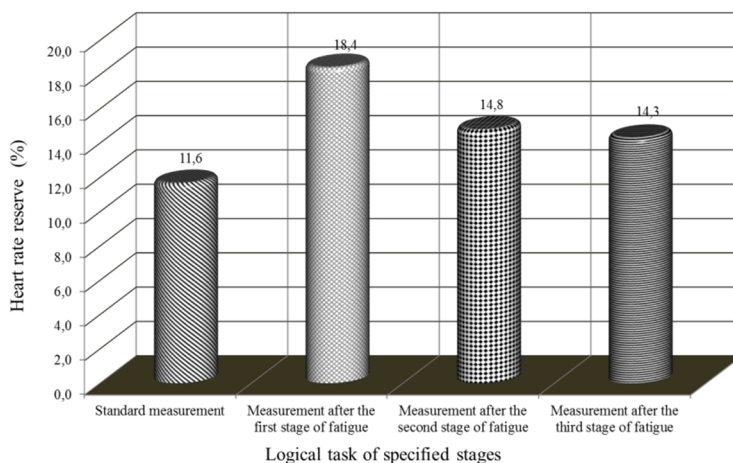


Figure 8. The index of heart rare reserve at particular stages of the experiment

The highest because 18.4% index of using the heart rate reserve was reported after the first stage of fatigue "B" i.e. after the part verifying the knowledge of the experimental group on sub-assemblies and procedures included in the tractors user's manual analysed for 30 minutes. It should be emphasised that it was a value 1.59 times higher than the heart rate reserve index which was reported at the standard measurement. Taking into consideration mean values of the heart rate reserve for subsequent stages of the experiment, a classification of the effort can be made. However, the index of using a heart rate reserve in any case does not exceed 25%, thus the level of burdening with work may be classified as very low. Five statistically significant differences in the mean values of the analysed parameter out of six possible were reported (table 4).

Table 4

The results of Tukey's test for testing statistical significance of differences of the heart rate reserve between particular stages of mental fatigue

Stages of experiment	A	B	C	D
Standard measurement (A)	X	X	X	X
Measurement after the first stage of fatigue (B)	*	X	X	X
Measurement after the second stage of fatigue (C)	*	*	X	X
Measurement after the third stage of fatigue (C)	*	*	---	X

\* statistically significant error

--- no differences

No statistically significant differences were reported only between the value of the heart rate reserve in case of the test after the second stage of fatigue "C" and the test carried out after the third stage of fatigue "D".

## Conclusion

It was reported that along with the increase of the mental fatigue, time necessary to accomplish a single logical task increases. A possible decrease of the absolute time necessary to accomplish a task may result from the process of learning how to answer specific logical tasks and accustoming the tested persons with the procedures. It was proved that the factor which causes the highest increase in the number of heart contractions is mainly stress caused by a quantity control of the possibility of learning given units in the set time interval. While, the highest number of mistakes was reported after the practical part of the experiment, which proves that real use of knowledge in practice generates the highest mental fatigue of a body.

## References

- Buchberger, J. (1984). *Die Beurteilung von Arbeitsbeanspruchungen aufgrund der kontinuierlich registrierten Herzschlagfrequenz*. Arbeitsärztlicher Dienst des BIGA, Bern. Arbeitsmedizinische Informationen, Nr.12.
- Cieź, J. (2008). *Stres jako przyczyna wypadków w świetle literatury zagranicznej*. Stres w pracy i życiu rolnika - jego skutki zdrowotne. IMW Lublin, 120-127.
- Groborz, A.; Juliszewski, T. (2005). Tętno jako wskaźnik obciążenia pracą w fermie krów mlecznych. *Inżynieria Rolnicza*, 10(70), 107-115.
- Juliszewski, T. (2008a). Some ergonomic problems of utilization of signaling devices of the modern agricultural machines. *Journal of Research and Applications in Agricultural Engineering*, Vol. 53(1), 9-11.
- Juliszewski, T. (2008b). Komputerowy test do szacowania obciążenia pracą umysłową. *Inżynieria Rolnicza*, 7(105), 79-83.
- Juliszewski, T.; Kielbasa, P. (2010). *Urządzenia sygnalizacyjne ciągników i maszyn rolniczych*. Poznań, PWRiL. ISBN 978-83-09-99034-5.
- Juliszewski, T.; Kielbasa, P. (2012). *Ergonomiczne aspekty obsługi komputerów pokładowych wybranych ciągników rolniczych*. Czynniki ludzkie a bezpieczeństwo i higiena pracy w rolnictwie. Lublin, Instytut Medycyny Wsi. ISBN 978-83-7090-129-5.
- Juliszewski, T.; Kielbasa, P.; Bąba, S. (2013). *Ergonomiczna charakterystyka urządzeń sterowniczych we współczesnych ciągnikach rolniczych*. Praktyczne problemy związane z ochroną pracy w rolnictwie. Instytut Medycyny Wsi. Lublin, ISBN 978-83-7090-129-5.
- Olszewski, J. (1997). *Podstawy ergonomii i fizjologii pracy*. Poznań, Wyd. Akademii Ekonomicznej. ISBN 83-85530-90-8.
- Wróblewska, M. 2004. *Ergonomia skrypt dla studentów*. Opole, Wyd. Politechniki Opolskiej. ISSN 1427-9932.
- Złowodzki, M.; Juliszewski, T. (2011). *Ergonomia wobec obciążeń pracą umysłową*. Obciążenie psychiczne pracą-nowe wyzwania dla ergonomii. Komitet Ergonomii. Kraków, PAN. ISBN 978-83-61236-14-6.
- Zdrowie psychiczne w środowisku pracy-wyniki działań prewencyjnych państwowej Inspekcji Pracy*. Warszawa, Państwowa Inspekcja Pracy, 2012. Pozyskano z: [http://top.sejm.gov.pl/1\\_0ld/opracowania/pdf/material59.pdf](http://top.sejm.gov.pl/1_0ld/opracowania/pdf/material59.pdf).

*Sprawozdanie Głównego Inspektora Pracy z działalności Państwowej Inspekcji Pracy. (2007). Państwowa Inspekcja Pracy. Pozyskano z: [http://www.pip.gov.pl/pl/o-urzedzie/sprawozdania-z-dzialalnosci/15367\\_sprawozdanie-glownego-inspektora-pracy-z-dzialalnosci-panstwowej-inspekcji-pracy-2007.html](http://www.pip.gov.pl/pl/o-urzedzie/sprawozdania-z-dzialalnosci/15367_sprawozdanie-glownego-inspektora-pracy-z-dzialalnosci-panstwowej-inspekcji-pracy-2007.html).*

## **WPLYW RODZAJU CZYNNOŚCI UMYSŁOWEJ NA ZMĘCZENIE PSYCHICZNE I STOPIEŃ OBCIĄŻENIA FIZJOLOGICZNEGO PRACĄ**

**Streszczenie.** W pracy podjęto próbę określenia wzajemnych relacji między długością i rodzajem czynności związanej z pracą umysłową a stopniem znużenia psychicznego i wskaźnikiem rezerwy tętna. Badania przeprowadzono na grupie 25 osób, które realizując poszczególne etapy procesu szkolenia dotyczącego obsługi współczesnych ciągników rolniczych poprzez specjalne testy logiczne i pomiar tętna generowały informację dotyczącą zmęczenia psychicznego i występującego w czasie eksperymentu stresu. Stwierdzono że wraz ze wzrostem długości pracy umysłowej zwiększa się czas potrzebny do wykonania zadania logicznego i liczba popełnianych błędów. Zaobserwowano również, że z każdym następnym testem o podobnej konstrukcji logicznej zmniejszał się czynnik stresu oraz następował proces uczenia się badanych osób, dlatego w czasie ostatniego pomiaru badana grupa uzyskała relatywnie lepsze wyniki niż w teście wykonanym wcześniej.

**Słowa kluczowe:** znużenie psychiczne, ergonomia, tętno, praca umysłowa