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Application of bioelectrical brain activity research to assess the level of attention of a farm tractor operator

Streszczenie. *Celem badań była analiza uwagi operatorów ciągnika rolniczego podczas prac polowych. Zakres prac obejmował badanie poziomu sygnałów EEG u 4 kierowców podczas jazdy ciągnikiem przy jednoczesnej pracy systemu nawigacyjnego oraz analizę uzyskanych wyników. Sygnały EEG kierowców zostały przetestowane za pomocą neurohełmu Emotiv Epoc Flex. Określono poziom fal beta (Low Beta i High Beta) odpowiedzialnych za uwagę i przeanalizowano zmienność poziomu.* ***(Zastosowanie badań bioelektrycznej aktywności mózgu do oceny poziomu uwagi operatora ciągnika rolniczego)***

Abstract. *The aim of the research was to analyze the attention of a farm tractor operators during work performed in the field. The scope of work included the testing of the level of EEG signals in 4 drivers while driving a tractor with simultaneous operation of the navigation system and the analysis of the obtained results. Drivers' EEG signals were tested with the Emotiv Epoc Flex neuro-helmet. The level of beta waves (Low Beta and High Beta) responsible for attention was determined and the variability of the level was analyzed.*

Słowa kluczowe: elektroencefalografia, bioelektryczna aktywność mózgu, neurohełm, zaangażowanie uwagi
Keywords: electroencephalography, bioelectrical brain activity, neurohelmet, attention involvement

1. Introduction

Human work is usually analyzed in conjunction with the means of work and organizational and technical factors present at the workplace. Therefore, ergonomic research is mainly based on the human-work relationship, and when considering this relationship, the employee's ability to perform a given activity must be accurately assessed. Thus, it is necessary to determine the psychophysical effort that the work generates and the conditions accompanying it [1]. Psychophysical and physical effort is understood as physical and mental burdens arising during the performance of professional duties/activities. Physical burden result directly from the work of the muscles, whether it is dynamic or static. Mental effort, in turn, is the result of attention and thought processes. What has the strongest influence on the level of mental effort is the concentration of attention [2].

It should be noted that the development of mechanization and automation of work and the increase in the share of intellectual work in many branches of the economy often almost eliminates the physical effort of the employee, while increasing the risk of mental overstrain. This principle also applies to workers in the agricultural sector, such as operators of tractors and agricultural machinery. The result of such increased mental and psychological effort may be excessive mental fatigue, resulting in a decrease in the employee's productivity. The consequence of many years of work in conditions of mental fatigue and stress is burnout in the young generation of employees. It seems, therefore, that for ergonomic and organizational reasons, the key element is to determine the mental effort in each workplace. There are still no methods that can clearly determine the level of mental fatigue. However, it is possible to control the factors influencing this burden and, on this basis, to formulate guidelines enabling e.g. reorganization of work. One of the factors significantly influencing the level of mental stress is attention, i.e. the state of concentration of the mind (e.g. on objects, facts or experiences). It is also the ability to select stimuli from the external environment. Attention plays an important (if not the most important) role in mental work. Maintaining a high level of sustained attention for a long time depends on the activation of nerve cells in the brain [3]. For full active cooperation, external stimuli are needed, i.e. stimuli independent of the human will. Internal stimuli (focused on a single target) also participate in cellular stimulation, but are less active [4]. A review of the literature on the functioning of attention shows the multiplicity and ambiguity of definitions and approaches to the phenomenon of attention. Some of them emphasize the relationship of attention with perception processes, others associate it with executive control that the human mind will exercise in the course of complex tasks [5, 6]. The first approach is more strongly associated with psychological considerations about the essence of attention processes, while the second is characteristic of the neurological approach, which is based mainly on the achievements of neurology, psychiatry and biochemistry [7]. Nowadays, attention is most often defined as a system responsible for selecting information and preventing the negative effects of overloading the cognitive system with excess data. It is often stressed in the literature on the subject that the essence of the functioning of such attention is selection, i.e. the selection of a single object of perception or topic of thinking, with this selection relating both to perception and higher mental functions [7, 8].

The neuroanatomical background of attention processes involves many structures, but the main role is played by two centres: the posterior part of the parietal lobe (responsible, among others, for visual attention and perceptual search) and the right frontal lobe (responsible, among others, for attention vigilance, long-term concentration) [9]. Psychodiagnostics has long had a number of methods, especially clinical trials, which are successfully used in neuropsychological studies carried out according to the clinical-experimental paradigm. There are plenty of techniques for examining attention (and all its features). They also allow to estimate the level of attention involvement (i.e. the level of its concentration, focus). These methods can be divided into psychological and physiological, or psychological-physiological methods. Moreover, psychological and physiological methods are used, which use biomedical engineering tools to record physiological indicators of the body's response to activities. The most popular of these methods is electroencephalography, which is a study to record the electrical activity of the brain. A variety of brain waves are used to measure the level of attention with electroencephalography. The beta waves are definitely the most useful in the study of attention span and related disorders. This is confirmed by numerous studies on the level of attention, monitoring this level, and research aimed at detecting problems with attention [10-19].

2. Aim and scope of research

The aim of the study was to check the possibility of controlling the level of attention of farm workers who perform field activities. The scope of work included testing the level of EEG signals in 4 employees while driving a tractor in the field. Only men were among the employees selected for the study. Their ages were as follows: 29, 31, 58, 36 (years old). Each of them had experience in driving a farm tractor. This experience was 11, 4, 41, 18 (years old). While driving, the driver's task was to focus his attention on the navigation indications on parallel lanes, which allows him to make even runs and thus - the maximum cleaning of the field surface.

It seems that monitoring the variability of the level of attention in these employees may allow the detection of a constant moment of decreased concentration of this attention, which may contribute to the correction of the work schedule, introducing breaks, and, consequently, increasing the efficiency of the driver.

To prove this thesis, the following research steps were required: calibration of the measurement system, EEG measurements on four drivers, conversion of saved data (from movie to numerical), analysis of reported data, developing applications.

It should be noted that the drivers were to perform journeys according to the navigation indications, and the degree of their concentration was assessed by the results of the correctness of these journeys (i.e. the accuracy of the traveled route in relation to the set one).

3. Research methodology

To test the EEG signals, EMOTIV's wireless EPOC FLEX electroencephalograph, commonly known as the neurohelmet, was used. The EPOC Flex Neurohelmet is a wireless device. It has 32 electrodes permanently placed in appropriate places, fixed on a flexible cap, which is put on the head of the test person (Figure 1). These electrodes measure changes in electrical potential on the skin surface.

Fig. 1. EMOTIV EPOC FLEX Neurohelmet [20]

The EPOC FLEX device, hereinafter referred to as the neurohelmet, operates on the principle of a simplified electroencephalograph. Although their performance is less than that of a classic electroencephalograph, the wireless form of the apparatus allows for the use of electroencephalography in studies outside the laboratory or the office of a specialist. It is very important from the point of view of the conducted research, because the wireless form of the apparatus allowed for the tests to be carried out in the field.

The test begins with the assembly of the helmet. The electrodes are mounted in advance on a flexible cap, which is put on the test person. The electrodes must be moistened with a highly conductive gel, which facilitates the reception of signals. The examination started with checking the correct placement of electrodes. For the electrodes to read the signal correctly, good conductivity had to be ensured. Highly conductive gel was applied to the skin surface, under each electrode, for recording the EEG curve. The software that cooperates with the apparatus allows to control the quality of the signal recorded by each electrode. On one of the interfaces of the software it is possible to display a sketch of the arrangement of electrodes. It is worth to work on wearable equipment which use the wearable solutions [21].

After the electrodes have been properly connected, a proper EEG test was started. The result is represented in real time, in the form of a chart - electroencephalogram, from each electrode separately. The record from each test can be saved, played back and stopped repeatedly. This form enables a deeper analysis of the results. In addition to the EEG chart, which is difficult to interpret by a non-expert person (the analysis of neuroimaging results in the form of an electroencephalogram is usually done by doctors, possibly biomedical engineers), it is possible to record the level of involvement (in the program marked as power) of brain waves at specific frequencies. This allows us to see whether there is greater involvement of the waves responsible for concentration (like beta waves) or, for example, waves that represent a relaxation of the mind and meditation. At this point it should be noted that this chart does not serve to compare the level of engagement of individual waves, because the intensity of one frequency does not mean the absence of the others, just as the action of one brain area does not exclude the simultaneous action of the others. However, it is possible to observe changes in the level of engagement of selected waves while performing a given activity. In the case of beta waves, it gives the opportunity to notice a decrease in attention engagement, which is noted as a decrease in the frequency of these waves engagement.

The software enables the display of results for the following predetermined intensities of the frequency bands: Theta (4-7.5), Alpha (8-11.5), Beta (12 - 24.5) and Gamma (25-45). A significant amount of signal processing and filtering is included in the kit to remove mains noise and harmonic frequencies. This is why the signals appear clear when good contact quality is achieved. Sampling is done at 2048 Hz, a double notch filter at 50 Hz and 60 Hz and a low pass filter at 64 Hz are used, then the data is filtered to 128 Hz or 256 Hz for transmission.

The test persons performed the same activities: they were supposed to cross a selected area of the field according to navigation indications on parallel lanes (figure 2), with a given speed of 7 km / h. The tractor worked without an aggregated machine. The driver's task was to steer the vehicle, focusing on its operation, navigation and maintaining the set speed. Before the test run, the device (neuro-helmet) was calibrated according to the attached instructions.

Each time, the journey lasted 30 minutes and was performed right after the driver started working, i.e. in the morning.

3.1. Calibration and noise

With conventional EEG systems, the challenge is to eliminate the effects of muscle signal from brain patterns, and most medical EEGs require the patient to sit very still so that the brain signals can be seen with sufficiently high integrity. Neurohelmet EMOTIV has sensors located around the frontal and prefrontal lobes, which thanks to their location also receive signals from the muscles of the face and eyes. The EMOTIV detection system filters these signals and treats them as noise so that the results are not distorted by artifacts. The developed classifiers can detect many facial expressions, including the blink of the left and right eyes or the blink of both, eyebrow raised (as in surprise), frown, smile, and clenched jaws. These gestures are used to calibrate the system before starting the measurements.

After calibrating the system, each driver (before starting the actual measurement) was supposed to cover a short stretch of an undemanding (i.e. asphalt, straight) road with maximum concentration. At that time, EEG signals were recorded, which later, in the interpretation of the signals, served as a pattern of the expected focus on driving.

3.2. Conversion of results

All performed measurements were saved as files with the .edf extension . The EEG charts are also saved in numerical form, which can be reproduced in an MS Excel spreadsheet. The software does not give this possibility in the case of waveform power recording. Therefore, each of the records was played back and the result of beta wave involvement (lower and higher frequencies, marked as Low Beta and High Beta in the software) was manually recorded every second.

The chart of engagement of specific wave frequencies has been automatically scaled to a maximum value of 1, and a minimum value of 0. The value of the "power" of the specific waves is therefore expressed numerically and the result is in the range $<0,1>$. The range of the maximum value is set manually by the system operator. The authors chose to set this value to 1 as it can be equated to 100% and be a reference when comparing wave levels with each other. Thus, a data set was created in which values corresponding to wave activity were assigned for each second of measurement.

4. Research findings and their analysis

In 4 drivers performing the same field activities, an electroencephalographic examination was performed. The study included the recording of EEG signals during the test run (with controlled, high concentration while driving) and during standard runs in the field. The data was collected in the form of graphs showing the involvement of individual brain waves at different frequencies. The data was converted by recording the beta wave (low and high) second by second. The course of the graphs was analyzed, mean values and standard deviation were determined. Since it was assumed that a high level of concentration was achieved during the test run (as evidenced by the overlap between the set and actual routes on the navigation screen), the analysis consisted in comparing the beta wave level achieved during the test drive with the results of the beta wave level during standard field runs.

It is believed that the highest level of attention is characteristic of the so-called SMR sensorimotor rhythm, which is represented by beta waves with a frequency of 13-15 Hz [22]. This is observed in the sensory range of the cerebral cortex. It is a spindle-shaped wave. It determines the state of alertness, but without muscle tension. Waves with this frequency are classified as Low Beta in the Emotiv Epoc Flex software. However, since beta waves across the frequency spectrum characterize the normal daily activity of the human cortex, including sensory perception and mental work, the study also analyzed waves called High Beta (16-25 Hz) in the Empotiv Epoc Flex software.

The charts in figures 3-6 show examples of the results for driver no. 1. The ordinate (y) axis characterizes the beta wave level, and the abscissa (x) axis indicates the measurement time [s]. Figures 2 and 3 show the results of the low beta wave level during test drive and driving on field. Figures 4 and 5 are the results of the high beta wave level.

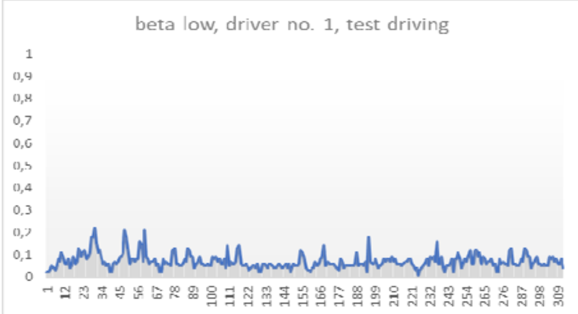

Figure 2. The level of low beta waves during a test driving performed by driver no. 1

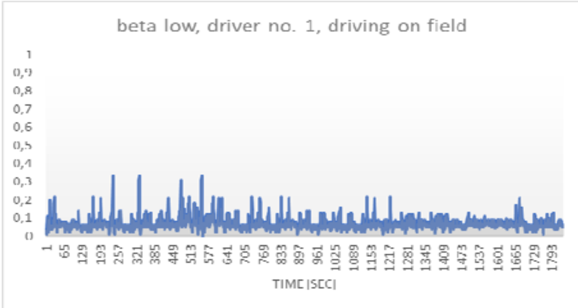

Figure 3. The level of low beta waves during a standard field driving performed by driver no. 1

The mean low beta value for the test task was 0.076 with a standard deviation of 0.042, and for standard off-road driving was 0.069 with a standard deviation of 0.036. Based on the course of these waves and the average value, it can be concluded that the employee's concentration during the 30-minute test while driving in the field reached a high level. Both measurements are characterized by a similar mean and standard deviation. Note that the test drive lasted around 5 minutes while the actual field test was around 30 minutes.

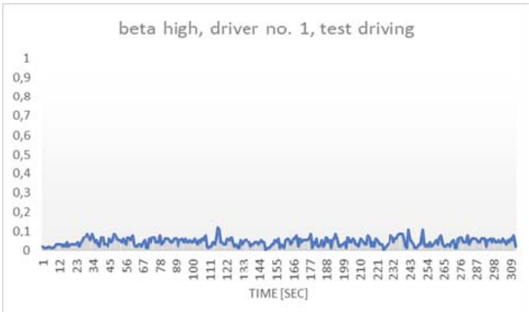

Figure 4. The level of high beta waves during a test driving performed by driver no. 1

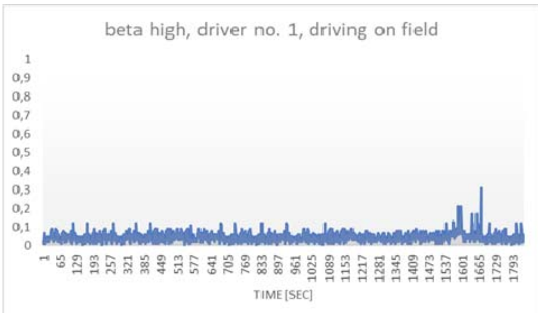

Figure 5. The level of high beta waves during a standard field driving performed by driver no. 1

The mean high beta value for the test run was 0.042 with a standard deviation of 0.021, and for the actual run was 0.044 with a standard deviation of 0.024. As in the case of the beta low waves, based on the average value and the waveform, it can be concluded that the focus on the task during the 30 minutes of the test reached a high level. But the differences between the time series of the beta low and beta high parameters were tested using the student's t-test (in the STATISTICA 13.1 program) for independent samples, at the assumed significance level of alpha = 0.05. The averages for the beta low wave level were, respectively: 0.070064 for the test run and 0.070316 for the field drive. The probability level of p = 0.904296 for the computed student t-test t = -0.120251 is greater than the assumed significance level of alpha = 0.05. The averages for the beta high wave were 0.042340 for the test run and 0.043984 for the field drive, respectively. The probability level p = 0.257937 for the calculated t-student test t = -1.13158 is greater than the assumed significance level alpha = 0.05. In connection with the described results, the hypothesis that there are no statistically significant differences between the two time courses were confirmed.

The article shows example charts for driver number 1. In the case of the remaining drivers, no significant anomalies were noticed in the course of the beta low and beta high charts, both during the test run and during work in the field. To confirm this, statistical calculations were performed for all test and field runs of each operator. In no case was the probability level higher than the assumed significance level.

It is possible that those drivers, driven by research, focused their attention on the task at hand. However, this does not invalidate the hypothesis that it is possible to monitor the driver's attention span when maneuvering in the field.

5. Summary and conclusions

Four drivers were tested on the level of brain waves. The results of the level of brain waves responsible for perception, mental involvement, state of active activity, wakefulness and alertness were analyzed. Stable involvement of these waves means that attention is focused on the cognitive tasks. A constant sensory rhythm (13–15 Hz), ie the low beta waves analyzed in the work, is observed when the mind achieves high concentration of attention. The analysis of the obtained test results showed that during the work in the field, a stable course of beta-low and beta-high waves was obtained, the same as in the case of the test run in which the results of the route were assessed. This means that the level of focus on the tasks entrusted was high.

Based on the conducted research, it can be concluded that continuous monitoring of the level of waves with specific frequencies may enable the development of optimal time standards for the employee. The time standards for performing individual tasks always arouse emotions and are often the subject of conflicts between the employee and the employer. The overriding goal of the employer is to optimize costs by increasing the work efficiency of his employees, and the employee cares about respecting his working time and optimizing the scope of his duties. The use of permanent or temporary monitoring of the drivers' concentration level would allow for the development of an individual work plan, consistent with the capabilities of the employee's mind. This will allow the driver to adjust the working time (i.e. the length of work between breaks) to his mental abilities. In addition, the quality of his tasks (e.g. field trips) will be high, which will contribute to increasing economic indicators (e.g. effective use of the field area while sowing crops).

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