Ministry of Education and Science of Ukraine

Odessa National Academy of Food Technologies

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2021

Information Technology, Automation and Robotics

Proceedings

Odessa, ONAFT 2021

UDC 004.01/08

Editorial board:

Black Sea Science 2021: Proceedings of the International Competition of Student Scientific Works. Information Technology, Automation and Robotics. / Odessa National Academy of Food Technologies; B.Yegorov, M. Mardar, S.Kotlyk (editors-in-chief.) [*et al.*]. – Odessa: ONAFT, 2021. – 526 p.

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INVESTIGATION OF THE INFLUENCE OF EXTERNAL FACTORS ON THE POTENTIAL PERFORMANCE OF A PERSON AT THE COMPUTER AND HIS BRAIN ACTIVITY

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Abstract. *This study aims to create tools to maximize the potential performance of a person at the computer. The effects of mental fatigue on efficiency and, consequently, on productivity is difficult to overestimate. People who work a lot at the computer are particularly prone to high cognitive load and, as a result, loss of motivation and poor performance. In this work, experiments were performed to change the usual parameters of the environment during the working day and investigated their impact on the efficiency of human interaction with the computer and its electrical activity of the brain. The hypothesis of a correlation between electroencephalographic data collected using a portable neurointerface and mental fatigue has been partially confirmed. The created software-hardware system based on the obtained results will be a useful tool for optimizing the working conditions of employees in the IT field and others.*

Keywords: *EEG, programming, mental fatigue, neurointerface, statistic analysis, efficiency.*

I. INTRODUCTION

Due to the technological boom in the last two decades, the percentage of jobs for people who are exposed to cognitive stress on their brain has increased many times, outweighing the percentage of jobs with physical activity. There is a growing demand for high-quality software to solve various problems in our world. At the same time, the profession of a programmer is currently one of the most paid and one of the most popular in the world. To meet this above-mentioned need, and at the same time make good money, software developers are very often in suboptimal conditions, and do not have any opportunity and time to optimize these conditions.

All this puts developers in a situation where they have to work in a tired state. Software errors can be the result of poor developer performance, which is often a direct consequence of lack of attention or exhaustion, including due to unfavorable working conditions. They try to focus, but due to fatigue, even the simplest tasks take longer time. Most people do not even think about how monotonous work at the computer affects the biophysical and electrophysiological parameters of their body. Very noticeable and important changes can be seen both in the work of the brain, which is expressed by the rhythms of human brain activity, and in the performance of the person himself at the computer, which can be tracked by analyzing interaction with input devices.

Our overall goal of the study is to search for dependencies of human stylometry data, that is, the speed of interaction with a computer, its electrophysiological indicators, various subjective indicators from various factors that can affect a person and his fatigue rate during programming tasks, determining potential methods for predicting the onset of fatigue, creating possible algorithms for improving the potential performance of a person.

We also aim to determine whether there is a correlation between the speed of a person by working at a computer, as an objective indicator for determining the level of his fatigue and the electrical activity of the brain in order to answer the question: "Can the data of the human brain collected by electroencephalography method using a portable neurointerface be considered as an objective indicator for determining the level of mental fatigue of a person?".

II. LITERATURE ANALYSIS

Currently, the human-computer system can be considered as an adaptive system that requires its own study, especially in modern conditions. This system serves human-computer interaction and helps the computer user better interact with various aspects of the computer interface. During the research of a person, as part of an adaptive system, cognitive (measurements of electrical activity of the brain), cardiovascular measurements, and human stylometry measurements can be used, that is, quantitative assessment of the speed and accuracy of human interaction with a computer to assess the functional state of the operator. It is also worth to note that the use of many types of monitoring provides greater accuracy in assessing the human condition than in the case of any measurement separately. One of the promising methods, as noted by researchers such as B. Jap, S. Cheng, and L.Trejo is the use of electrophysiological indicators to assess changes in the functional state of an operator using electroencephalography (EEG) [1-3]. This information is collected through sensors in real time, in an attempt to identify moments of increased demand for the operator's cognitive resources and find a way to bring these resources to a level adequate to the requirements of the task performed by the operator.

In the case of studying the condition of worker who works with computer or computerized systems, it is advisable to use brain-computer interfaces (BCI), the principle of operation of which, for the most part, is based on EEG technology. In their paper, B. Lance and K. McDowell described potential BCI technologies that target communication and other applications. They also focused on possible future applications that will be based on relatively predictable breakthroughs in sensor, analytics, and computing technologies. Also, according to the authors, in the near future, applications that are being developed are likely to be focused on tasks where neural signals can provide information that is difficult or even impossible to obtain using other methods, on tasks where very high accuracy of interpretation of results will not be required (due to a very large number of obstacles that will arise in the near future) and on tasks that will assess the general state of mental fatigue of a person, instead of relying on separate data from different types of cognitive fatigue assessment. The authors also believe that in the near future, applications that will be developed are highly likely to be successful if they target a specific user using calibration or individual classification algorithms, instead of trying to perform work in broad groups or use normative population groups [4].

At the same time, BCI, as just one of the elements of the system that will help a person improve their performance at the workplace, should be compact, convenient and not very expensive. An example of research using such a tool is the work of H. Al-Libawy and W. Al-Nuaimi. Their proposed method measures the effect of fatigue in real time depending only on the EEG signal to the subject, that is, it is completely independent of the type of load, which makes it suitable for most applications, such as fatigue of truckers, pilots, machinists, programmers, general monitoring, etc. The proposed system will not be very expensive compared to other systems, since it is based on a relatively inexpensive device – MindWave Mobile. Under experimental conditions, the system showed a fairly accurate result, but still needs to be tested under real-world operating conditions. The authors of this article confirm and consider it quite important to use several fatigue monitoring systems to improve the reliability of an integrated system [5].

Another aspect of monitoring of a person's fatigue level can be used to assess the speed and accuracy of human interaction with a computer using a keyboard and mouse. The so-called human stylometry. In the work of A. Pimenta and co-authors, an approach to classifying the level of mental fatigue of people who uses a computer was presented by analyzing their interaction patterns, in particular aspects of using the mouse and keyboard. The most notable aspects of this paper are that it details a non-invasive and transparent approach to problem solving, while other approaches are based on questionnaires or physiological sensors, which have a number of drawbacks. The presented approach is based on an analysis of the behavior of a particular user [6]. In the works of A. Pimenta and S. Sarkar, the possibility of assessing the level of human fatigue based on monitoring its stylometry was thoroughly investigated, and how exactly mental fatigue affects the quality of work, including during solving programming problems. The obtained results prove not only the effect of fatigue on the user's productivity during the day, but also that it is possible to measure and classify these effects in real time [7, 8].

L. Barker believes that the identification of states of increased mental load in an employee is an absolute priority, since excessive workload can have a bad effect on working information that is absorbed by the operator [9].

The use of several separate systems at once, which allow you to assess the level of cognitive fatigue of a person to one degree or another, in addition to increased accuracy of assessment, also provides almost unlimited opportunities for statistical processing of these data. That is, you can simultaneously track the level of correlation between indicators provided, for example, by electroencephalography and indicators provided by the system for tracking human interaction with the mouse and keyboard.

A study conducted by I. Khan and co-authors indicates that the level of cognitive fatigue and the rate at which this fatigue occurs can be directly influenced by various internal factors (a person's well-being, general physical condition) [10]. And the research of T. Shishelova and co-authors and the research of S. Folkard and P.Tucker show that this is also influenced by external factors (ambient temperature, pressure, humidity level, workplace illumination level, time already spent at work, the presence of background noise, music, etc.) [11, 12]. A B. Jap and co-authors proved that the degree of psychological and physiological perception of acoustic stress is influenced by the type of higher nervous activity, individual biorhythmic profile, the nature of sleep, the level of physical activity, the number of stressful situations during the day, the degree of nervous and physical overstrain [1]. Therefore, the full task will be to develop a system that would make it possible to search for the dependence of a person's fatigue level on all the above indicators.

A system that will simultaneously have access to such a large amount of data can be successfully used to predict the future state of the user based on previously conducted analyses, to find the "strongest" factors in the level of influence on the rate of onset of human fatigue, to provide the user with advice during work when and how much he should take a break, and, as a result, to increase the level of labor productivity, the quality of work performed and reduce the overall load on the body.

A. Smith and C. Miles conducted a study that analyzed the effect of having lunch on cognitive alertness tasks, comparing the differences between participants who ate lunch and who remained hungry in the afternoon [13]. I. Khan and co-authors consider mood as a factor influencing the quality of software development results, which can also be used as an additional factor in analyzing the rate of fatigue onset in humans [10]. In addition to mood, stress, exhaustion, and drowsiness, some other factors that cause fatigue should be considered in the software industry. A number of studies show that mental fatigue affects various activities, such as reasoning, memory tasks, productivity, decision-making, and responsiveness [9, 14-17]. Fatigue, however, is usually described subjectively because of the variety of concomitant symptoms and causes that applies to a particular person. An industrial study would allow us to quantify the level of fatigue in the future and identify a number of objective symptoms of fatigue when performing general tasks related to the field of programming. Works of D. Nanghaka and H. Makabee [18-19], blogs [20] highlight the impact of fatigue on developer performance in tasks such as program understanding and decision-making. The study of B.Schneiderman and R. Mayer showed possible links between mental fatigue and specific programming tasks, such as program construction, modeling, and debugging [21]. As mentioned above, for any activity, context and environment are also very important for determining the level of fatigue during the day. For example, are these work-related variables, such as motivation, stress, boredom, or distraction; or environmental factors, such as the atmosphere, including temperature, noise, lighting; or even life factors, such as food, energy substances, such as caffeine. It is important to consider these contextual variables, as they can contribute to the fatigue that a person experiences.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of this study is the interaction of a person with a computer or computerized device in tasks that require high concentration and lead to a high cognitive load.

The subject of the study is a statistical analysis of the influence of various factors on the potential performance of a person at a computer and its relation with the electrical activity of the brain.

Research methodology:

The current study involves five students aged 21-25 years. Each participant was selected in accordance with a number of requirements: the absence of serious medical or psychiatric disorders at the time of testing; a ban on the use of any medications during testing and 24 hours before it starts; a ban on the use of alcohol and caffeine in any form 48 hours before the start of testing; the mandatory absence of such a bad habit as smoking.

The following time conditions were set for all test participants: mandatory full 8-hour sleep before starting testing. Work starts at 9 o'clock, ends at 18 o'clock with a lunch break from 13 till 14 o'clock.

To prevent the occurrence of any artifacts in the electroencephalogram data related to the physical activity of the body, test participants had to remove the neural interface from themselves during weaning and stop collecting information at this time.

All test participants performed a variety of programming tasks, each working at home.

The first part of the study, which was conducted for 5 consecutive days, was performed by participants in equal, almost constantly specified conditions. Where the ambient temperature was in the range of 22-24 degrees Celsius, the light level was maintained in the range of 240-250 lux, the atmospheric pressure was in the range of 1000-1050 gigapascals, humidity in the range of 38-42% percent. During the whole work, all participants had to be free of background noise, such as music, movies, etc.

As input devices, i.e. keyboards and mice, all participants used their own devices, which they have already used in their work for at least one year, that is, which they quite got used to.

During the whole research, programmers ' stylometry data was collected using background software and electroencephalography data was collected using the NeuroSky Mindwave Mobile 2 portable neural interface.

The purpose of this part of the study is to track how the above indicators change during the entire working day in equal conditions of different people, and to find out whether there is any relationship between the data on human fatigue, which reflects the performance indicators of his interaction with the computer, and between the brain activity that the data from the electroencephalogram will display.

The second part of the study consists of controlled changes in various factors during the whole working day, both environmental factors (light level, temperature, pressure, humidity) and working conditions (type of performed tasks, work schedule, presence of several breaks, meal schedule, presence of background music, if the participant considers this an improving factor).

During this part, participants were also taken survey using the NASA-TLX (Task-Load Index) method to obtain a subjective assessment of the level of comfort of working in certain conditions. Data on a person's potential performance under these variable conditions were compared with the reference data obtained in the first part of the study. There was also a comparison of data with the EEG.

The Arduino MEGA microcontroller platform with BMP-280 and GY-49 sensors and the NeuroSky Mindwave Mobile 2 portable neural interface are used as hardware tools for data collection. A software tool for recording and analyzing data is proprietary software created using the tools of the C# and .NET programming language.

The statistical tool for data analysis is correlation and variance analyse.

IV. RESULTS

Figure 1 shows graphs of keydown time (the average time that a person holds down the keyboard key) changes during the working day.

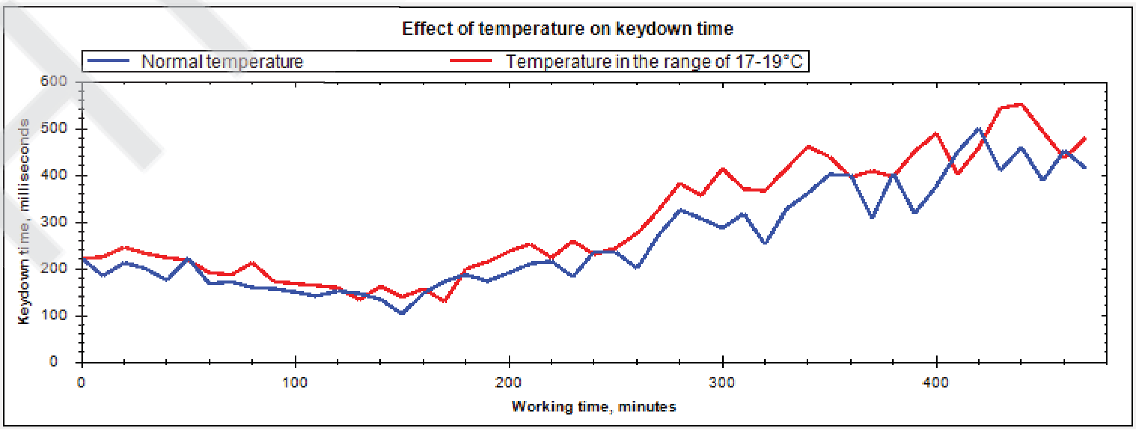

Fig. 1. The effect of temperature reduction on keydown time (less – better)

These graphs show that lowering the temperature from the usual 22-24 degrees Celsius for the home in winter to 17-19 degrees leads to an increase in average keydown time, especially it is noticeably closer to the evening, ie to the end of the working day. This can be explained by the fact that at the beginning of the working day the body still has energy, which allows you to fully warm the body despite the slightly colder conditions, and not allow the fingers to cool down.

Figure 2 shows graphs of mouse velocity (the average speed of the mouse cursor in pixels per second) changes during the working day.

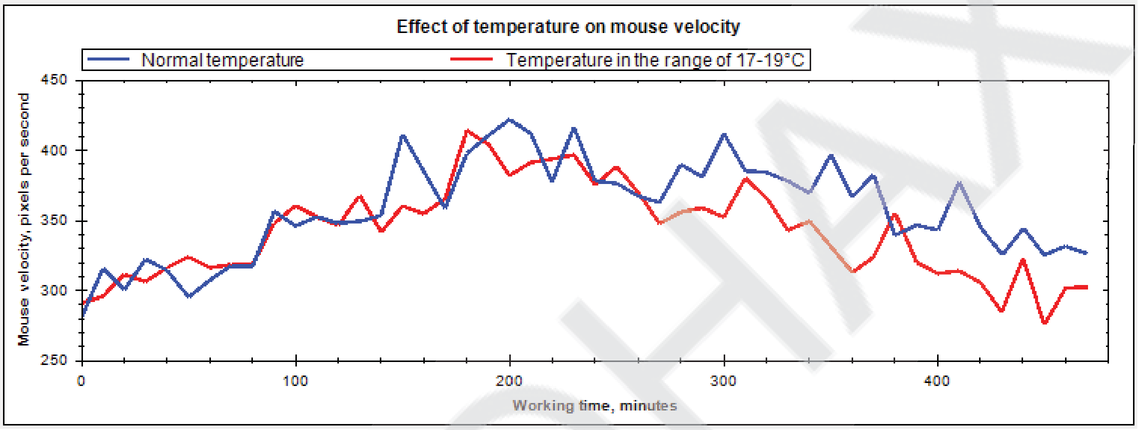

Fig. 2. Effect of temperature reduction on mouse velocity (more – better)

These graphs show that lowering the temperature leads to an increase in average mouse velocity, as in the previous case - it is especially noticeable near the end of the working day, which is also due to freezing of hands and loss of their control accuracy.

Figure 3 shows the results of NASA-TLX testing at the end of the working day under normal conditions and after changing the average temperature.

A subjective survey shows that when the temperature decreased, the most significant changes occurred in the physical load on the body, and the volunteer in the given conditions tried to finish his work as soon as possible, which may affect its quality. A subjective survey showed that the student's performance deteriorated significantly. The load level to achieve the required performance level has also increased. And the level of frustration became higher.

Figure 4 shows the graphs of EEG index changes (calculated index based on data from 5 ranges of brain rhythms, as the ratio of data from ranges corresponding to high brain activity to data from ranges corresponding to low activity) during the working day.

These graphs show that a decrease in the lighting level from the usual to the level of 10-30 lx leads to a slight decrease in the EEG index, especially noticeable in the morning, when the person is not fully awake, and we assume that bright light has a strong effect on awakening. And it's noticeable in the evening, when additional lack of lighting is a stimulus for drowsiness.

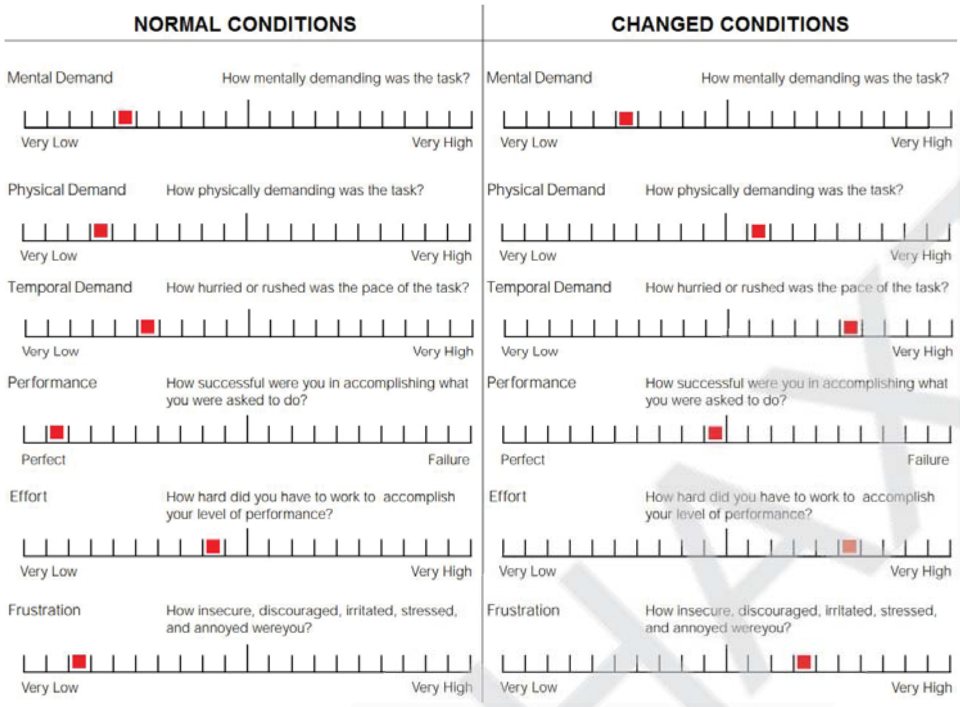

Fig. 3. Results of survey according to the NASA-TLX method before/after changing the average temperature

Figure 5 shows the results of NASA-TLX testing at the end of the working day under normal conditions and after reducing the lighting level.

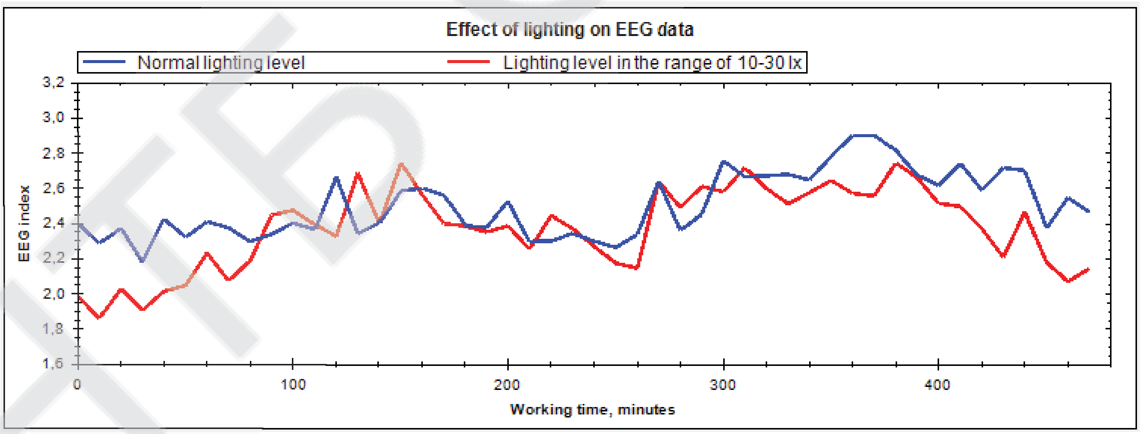

Fig. 4. Effects of reduced lighting level on EEG index (higher – better)

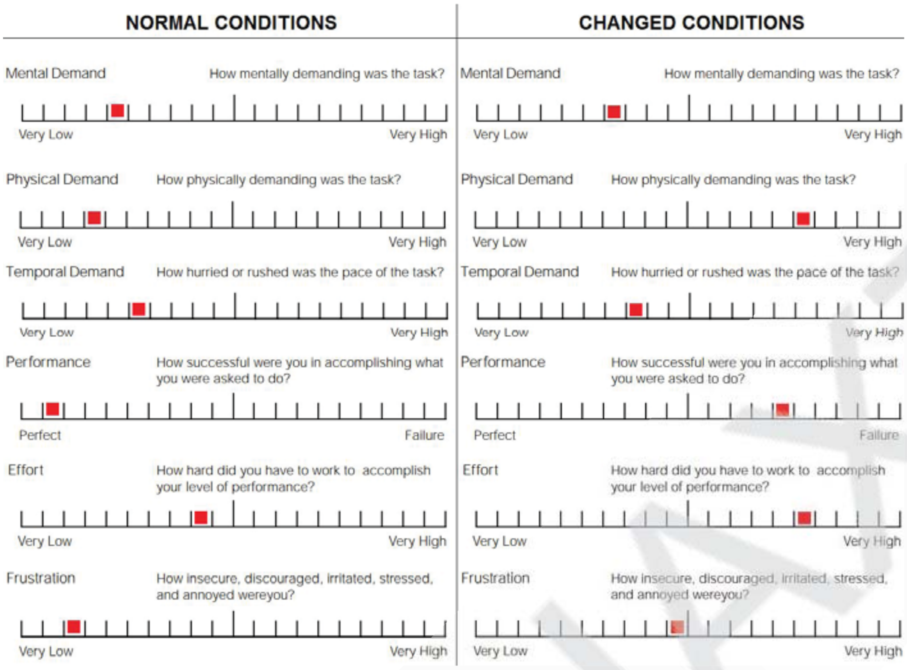

Fig. 5. Results of survey according to the NASA-TLX method before/after changing the lighting level

A subjective survey shows that with a decrease in lighting level, the most significant changes occurred in the physical load on the body. Working capacity has significantly deteriorated, and the level of workload has increased to achieve the same level of efficiency. The level of emotional comfort also deteriorated.

Figure 6 shows a comparison of keydown time and EEG index data graphs under normal conditions.

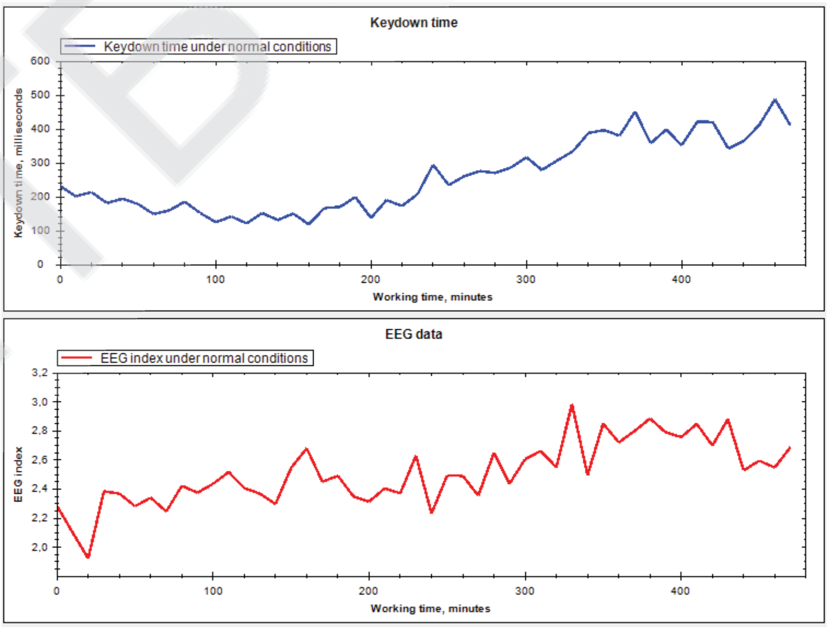

Fig. 6. Graphs of keydown time and EEG index changes during the working day

Examining these graphs, we can see a slight similarity between them, but very interesting is the fact that towards the end of the day with the deterioration of the efficiency of interaction with the keyboard also increases brain activity. This can be explained by the fact that when a person gets tired, he involuntarily begins to strain his mind more in order not to lose in the quality of the tasks performed, and this in turn can negatively affect his motor functions. Pearson's correlation coefficient with the current data set was 0.62.

Figure 7 shows a comparison mouse velocity and EEG index data graphs under normal conditions.

The next day we compared the results of mouse velocity and EEG index measurements, where the student mainly performed tasks in graphic design, where the mouse is very actively used. Looking at these graphs, it is difficult to draw any unambiguous conclusions. One can only notice that both mouse velocity and EEG index increase closer to the middle of the working day. Pearson's correlation coefficient with the current data set was 0.42.

V. CONCLUSIONS

In this study, with the help of the developed software-hardware system, the hypothesis about the influence of external factors on the potential performance of a person was tested. We have found that parameters such as air temperature and level of lighting can really have a significant effect on the effectiveness of human interaction with the computer. Furthermore, the effect of lighting level on the activity of the human brain was observed, from which it can be concluded that working with lack of lighting leads to a decrease in brain activity, especially in the morning and at the end of the working day. Moreover, we compared the dynamic of changes in human stylometric data with the dynamic of changes in brain activity. It may be the initial basis for confirming the assumption that human electroencephalogram data collected using a portable neurointerface can be considered as perspective effective indicator of mental fatigue, or at least used as an additional check of the psychophysiological state of man at work.

Further research should look more closely at the potential effects of changes in environmental parameters on a person's potential performance, both in terms of the effectiveness of interactions with the computer and in terms of brain activity. It will also be worthwhile to expand the scope of the study, namely to increase the number of people who will participate in the study, increase the time of the study and diversify the types of work performed. We consider that in addition to finding the above-mentioned dependencies, in the future we should focus on optimizing the conditions for each person for each specific type of work performed on the basis of previously obtained data. This is a good starting point for discussion and further research.

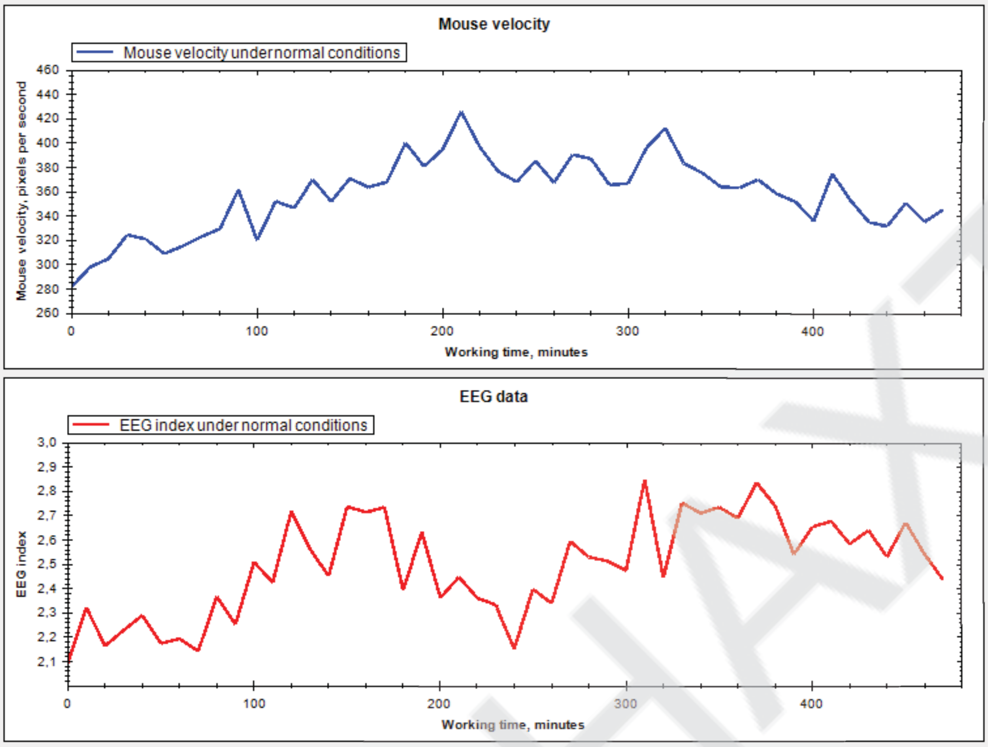

Fig. 7. Graphs of mouse velocity and EEG index changes during the working day

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PROSPECTS OF INTELLIGENT AUTOMATION IN SOFTWARE TESTING PROCESS

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Abstract. *This paper provides an overview of using Artificial intelligence (AI) for building test automation frameworks in a way with less human interventions. The analytical framework of the article is built on new modern enterprise prototypes.*

This article deals with opportunities as well as ideas to drive process of incorporation of AI in software testing process. The article provides analysis of areas to be augmented by use of Machine learning methods in testing tools (frameworks) from integrated reports as well as from own experience.

This article refers to improvement of software quality validation, discovering

International Competition of Student Scientific Works

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Responsible for the issue: Sergii Kotlyk

Computer typesetting and layout: Oksana Sokolova

Odessa 2021