

Software Platform for Learning about Brain Wave Acquisition and Analysis

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Abstract: Using brain waves, for user authentication, is an important emerging technology. The University of Defence, in the Belgrade and the Serbian Ministry of Defence (MoD), have recognized the importance of biometric applications in identity management. As a result, an intensive research, under the project named "Access control management of protected resources in Ministry of Defence and Serbian Armed Forces computer networks based on multimodal user identification", has been conducted over the last few years. The main contribution of this paper, is a software platform, for learning about brain wave acquisition and analysis. This platform was developed as a part of the project, with the main goal to improve and increase participant's knowledge in biometrics. A research study was conducted, with the aim of comparing traditional learning methods and learning methods based on the developed platform.

Keywords: biometrics; brain waves; learning tool; software platform; user authentication

1 Introduction

Access control to information systems is one of the most important aspects of protection, especially in systems that contain security sensitive data. It prevents people that have no rights to access a system and thereby misuse the information contained therein.

Traditional methods for establishing a person's identity are usually based on using passwords or tokens [1]. These methods have several disadvantages. Passwords are often used irresponsibly (they are usually designed to be easy to remember, or are stored inappropriately).

On the other hand, tokens can be intercepted and stolen. Therefore, there is a need for an alternative approach, biometric technologies can prove worthy. They provide the computer systems with the ability to identify a person using its physical or behavioral characteristics [2-4]. The main advantage of biometrics in comparison to passwords and tokens is the fact that biometric identity provides the information on who you are, rather than what you know (passwords), or what you possess (tokens). However, as biometric recognition relies on statistics, its output is not a yes/no decision, but matching score. This is a big disadvantage of biometrics as it leaves room for errors. Thus, there is a need to constantly improve precision of biometric systems, respecting biometric standards [5].

The University of Defence in Belgrade and the Serbian Ministry of Defence (MoD) have recognized importance of biometric applications for identity management. As a result, a project named "Access control management of protected resources in Ministry of Defence and Serbian Armed Forces computer networks based on multimodal user identification", it was started (VA-TT/3/18-20, 2018) with the main goal to design a modern, science-based model of managing access to protected resources of computer networks in the MoD and the Armed Forces, which will increase the reliability and security of computer networks, computer systems and their users. Achieving the basic goal is conditioned by the elaboration and realization of several sub-goals which are currently under development:

- Identification and scientific description of the existing model of managing access to protected resources of computer networks in the MoD and the Armed Forces
- Defining the strategy for managing access to protected resources of computer networks in the MoD and the Armed Forces
- Development of a model for selecting the optimal technology for registration, identification and authentication of resource users
- Development of models of security mechanisms for biometric data protection
- Development of security policy models

In order to achieve the stated sub-goals, we considered several biometric modalities, such as iris recognition, fingerprint and brain waves. We examined several presentations of these modalities. We found out that using brain waves, as biometric data for user authentication, was the most interesting and the most advanced technology for the participants, but most of them were unfamiliar with terminology. In order to overcome this issue, we developed an interactive software

platform for learning about brain wave (EEG) acquisition and analysis (eEEG) which is the main contribution of this paper.

In the next section, a brief overview of related research has been given. Section 3 contains overview of eEEG support platform and its functionalities. In section 4 we presented study settings, used methodology, profiles of participants, experimental results and discussion. In the last section, conclusions and further research are provided.

2 Related Work

Major research efforts in recent years were directed towards application of brain waves as a biometric characteristic that is unique and inherent for every person. The main challenge of this research is recreating the exclusive, person-related brainwave. EEG as a biometric characteristic lacks constancy and highly depends on stress, fatigue, medication, environment (electrical equipment) etc. To cope with this, researchers often use some kind of stimuli, to help in recreating the valid authentication EEG pattern, e.g. visualization of 3D object manipulation, counting, imagining letters and texts etc. [6].

Schomp [7] investigates the possibility of creating an authentication system based on the measurements of the human brain. An evaluation of the feasibility of brainwave authentication based on brain anatomy and behavior characteristics, conventional vs. dynamic authentication methods, the possibility of continuous authentication, and biometric ethical and security concerns are discussed. Jayarathne [8] provides an overview of crucial design considerations in handling EEG data for extended accuracy and practical applicability to authentication. Muhammad Azizi [9] discusses the applications of EEG as an alternative to mainstream biometrics. The state-of-the-art of several popular biometric modalities and technologies are outlined and specific applications where biometric recognition may be beneficially incorporated are provided by Ortega-Garcia [10]. Patrizio Campisi [11] recognizes many challenges which need to be properly addressed and represent an obstacle toward the deployment of biometric systems based on the analysis of brain activity in real life applications. He intended to provide a critical and comprehensive review of methods for EEG-based automatic user recognition. Campisi [12] shows that EEG is potentially more secure and privacy-compliant than traditional biometric identifiers. Reshmi [13] gives a novel approach on user recognition using EEG signals of brain. EEG recordings are acquired with portable and relatively inexpensive devices when compared to the other brain imaging techniques, like fMRI. The Emotiv EPOC EEG neuro headset with 14 saline electrodes and two reference sensors is used for the acquisition of brainwaves. Gui [14] presents an EEG-based biometric security framework. He proposed to reduce the noise level through ensemble averaging and low-pass

filter, extract frequency features using wavelet packet decomposition, and perform classification based on an artificial neural network. Experimental results show that the classification rates of distinguishing one subject or a small group of individuals (e.g., authorized personnel) from others (e.g., unauthorized personnel) can reach around 90%. Riera [15] presented authentication methodology using the experimental protocol that is common for EEG recording. Simple spectral features of the EEG are proposed by Miyamoto [16] to make the authentication system using the EEG more practical. The effectiveness of the proposed new features is evaluated in verification experiments with 23 users and the verification rate of 79% was obtained. Person identification based on parametric spectral analysis of the EEG signal is addressed by Poulos [17]. His proposed method was applied on a set of real EEG recordings made on healthy individuals, in an attempt to experimentally investigate the connection between a person's EEG and genetically-specific information. Paranjape [18] examines the effectiveness electroencephalogram (EEG) as a biometric identification of individual subjects in a pool of 40 normal subjects. The EEG's second order statistics are computed using autoregressive models of various orders. The coefficients in these models are then evaluated for their biometric potential. Discriminant functions applied to the model coefficients were used to examine the degree to which the subjects in the data pool can be identified. The results indicate that the EEG has significant biometric potential. Ravi [19] proposed a novel method to recognize persons using their brain patterns. These brain patterns are obtained when the individuals perceive a picture. High frequency brain energy is used as features that are classified by Elman backpropagation neural network. The experimental results using 1600 brain signals from 40 individuals give average classification rate of 96.63%. Nakanishi [20] examined the performance of verification based on the EEG during a mental task. In particular, assuming the verification of computer users, they adopted the mental task where users were thinking of the contents of documents. From experimental results using 20 subjects, it was confirmed that the verification using the EEG is applicable even when the users are doing the mental task. The system described by Soni [21] provides two-level authentication. First level is brain waves. Once the correct pattern of brain signal is provided the system will ask for a pass key as a second level of authentication. Nienke [22] explained what EEG devices do and do not measure. Ido [23] explains the brain-to-brain synchrony between persons (i.e., the similarity in their brain responses) and highlights recent developments in portable and wearable brain technologies. Shanmugam [24] gives different definitions of Brain computer interface and its types and how it can be used for authentication of a person. Sawsan [25] describes authentication system designed using the specified brain waves which are Gamma and Beta wave's features in order to generate the user authenticated sequence using Galois LFSRs.

3 The eEEG Software Platform Overview

The eEEG software platform consists of two applications. First, is for brain wave (EEG) data acquisition developed using C#, with Microsoft SQL Server as the database, for data storage. The second, is for brain wave analysis and visualization, developed in the ASP.NET technology. In the next sections, a brief overview of developed applications is described.

3.1 The eEEG Brain Wave Data Acquisition Application

In order to achieve the user identification phase, in terms of protection of information and communication systems, it is necessary to collect biometric data through biometric sensors which will be compared with already existing data registered in the system itself. The first step in creating such a system is the implementation of the data acquisition solution.

Acquisition is the collection of data from an external environment into a particular electrical device, i.e. a sensor. When it comes to biometric data, a biometric device for acquiring this type of data is required.

Biometric devices perform data acquisition by accepting data from a sensory receptor in the form of some sensation that occurs in or on the human organism and converts it to analog or digital signals that are used for further processing. The data thus collected can be used to identify particular person.

EEG authentication uses an electrophysiological system to monitor brain activity. This technology is very popular and can be used without any side effects on the brain.

There are several commercial devices with a variety of electrodes that are used to collect EEG data. Some of the sensors use dry electrodes, and some sensors use wet electrodes. The brain lobes emit EEG signals in response to different stimuli and mental states.

Neuro Sky Mind Wave 2-EEG device has been used for the purpose of collecting EEG data at this stage of project (Figure 1). This sensor performs measurement of alpha, beta, gamma, delta and theta brain waves, as well as the current state of focus - attention and relaxation of the subject whose brain waves are measured.

The screen of the software solution for EEG data acquisition from the sensor is shown in Figure 2. The solution was developed in the Microsoft Visual Studio 2017 using the C# programming language and the ThinkGear manufacturer's sensor library.



Figure 1

Neuro Sky Mind Wave 2-EEG device
 (<http://neurosky.com/biosensors/eeg-sensor/biosensors/>)

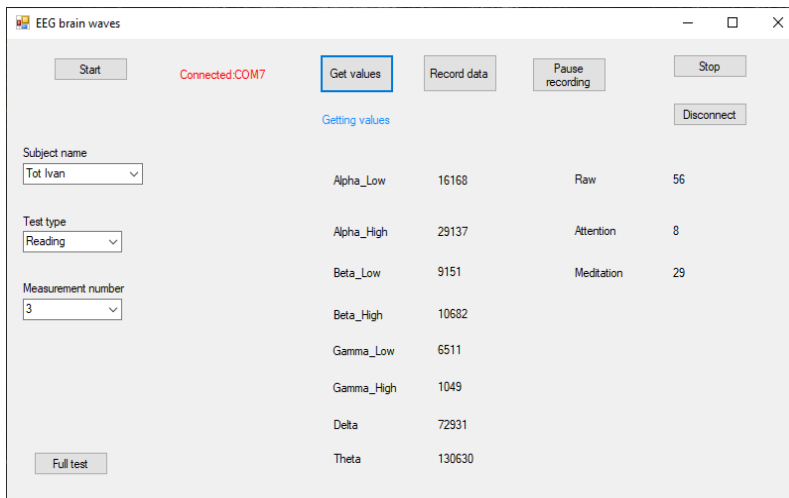


Figure 2

Software solution for EEG data acquisition

First, a Bluetooth connection with the sensor is established. After a successful connection, clicking the Get Values button will accept the values from the sensor and display them on the screen. The Stop button temporarily interrupts the acceptance of values from the sensor, and the Disconnect command button breaks the connection to the sensor.

Accepted values can be stored in a database implemented in Microsoft SQL Server Express 2014 by clicking the Full Test button. In this case it is necessary to choose the subject whose brain waves are measured, the type of test and the number of measurement. So far, we devised five types of tests:

1. Relaxed - the subject completely relaxes and closes their eyes
2. Reading - the subject reads text

3. Beautiful pictures - the subject looks at pictures that elicit positive emotions
4. Mathematics - the subject has a mathematical task that needs to be solved
5. Disturbing images - the subject looks at images that should elicit bad emotions (images of war crimes, mistreated animals, etc.)

Each one of the mentioned tests lasts for 20 seconds. During that time, at two second intervals, accepted values are stored in the database.

This procedure is conducted three times with each participant.

3.2 The eEEG Brain Wave Data Visualization and Analysis Application

To enable data visualization and analysis, a web application has been developed using Microsoft Visual Studio 2017 ASP.NET technology. The web application provides detailed information about alpha, beta, gamma, delta and theta brain waves. Moreover, in the application there are links which enable visualization, analysis and comparison of the obtained data as shown on Figures 3, 4 and 5. Finally, part of the implemented application is set of tasks in form of exercises for participants.

The web page shown in Figure 3 allows visualization and comparison of data obtained from the sensor for selected type of test, selected measurement and selected participants, by individual waves. The first-row charts show all the waves followed by charts that show the results of measurements performed by individual wave type (on the x-axis are time samples, and on the y-axis are the logarithmic values of the measured waves).

The web page shown in Figure 4 also allows visualization and comparison of data obtained from the sensor for a selected participant and selected type of test. For each measurement, columns show a summarized graph with all the waves (on the x-axis are time sample, and on the y-axis are the logarithmic values of the measured waves), followed by a single graph for each measured brain wave.

Finally, the web page shown in Figure 5, allows visualization and comparison of data obtained from the sensor by individual waves for a selected type of test and selected participant for all three measurements. Each chart shows the results of all measurements performed by wave types (on the x-axis are time samples and on the y-axis are the logarithmic values of the measured waves).

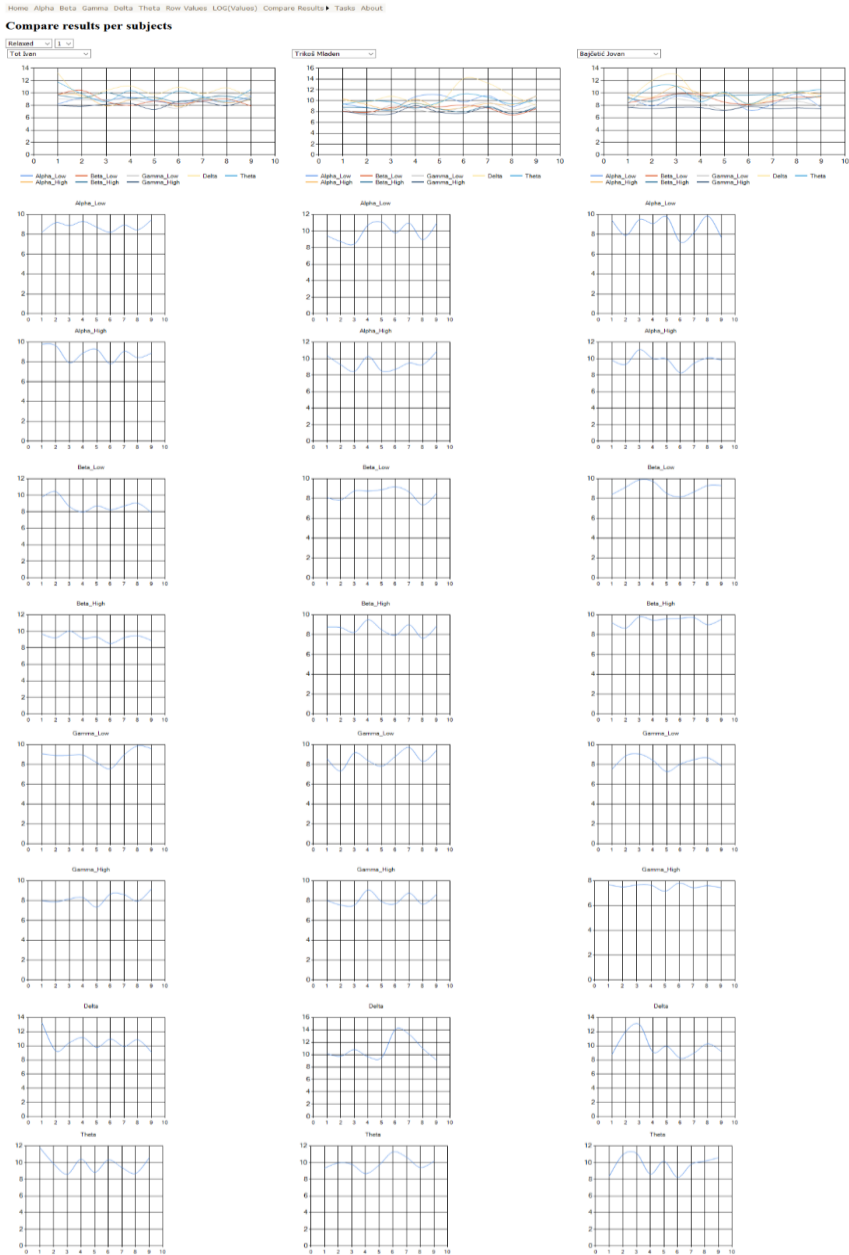


Figure 3
eIEEG web page for comparison of data per subjects

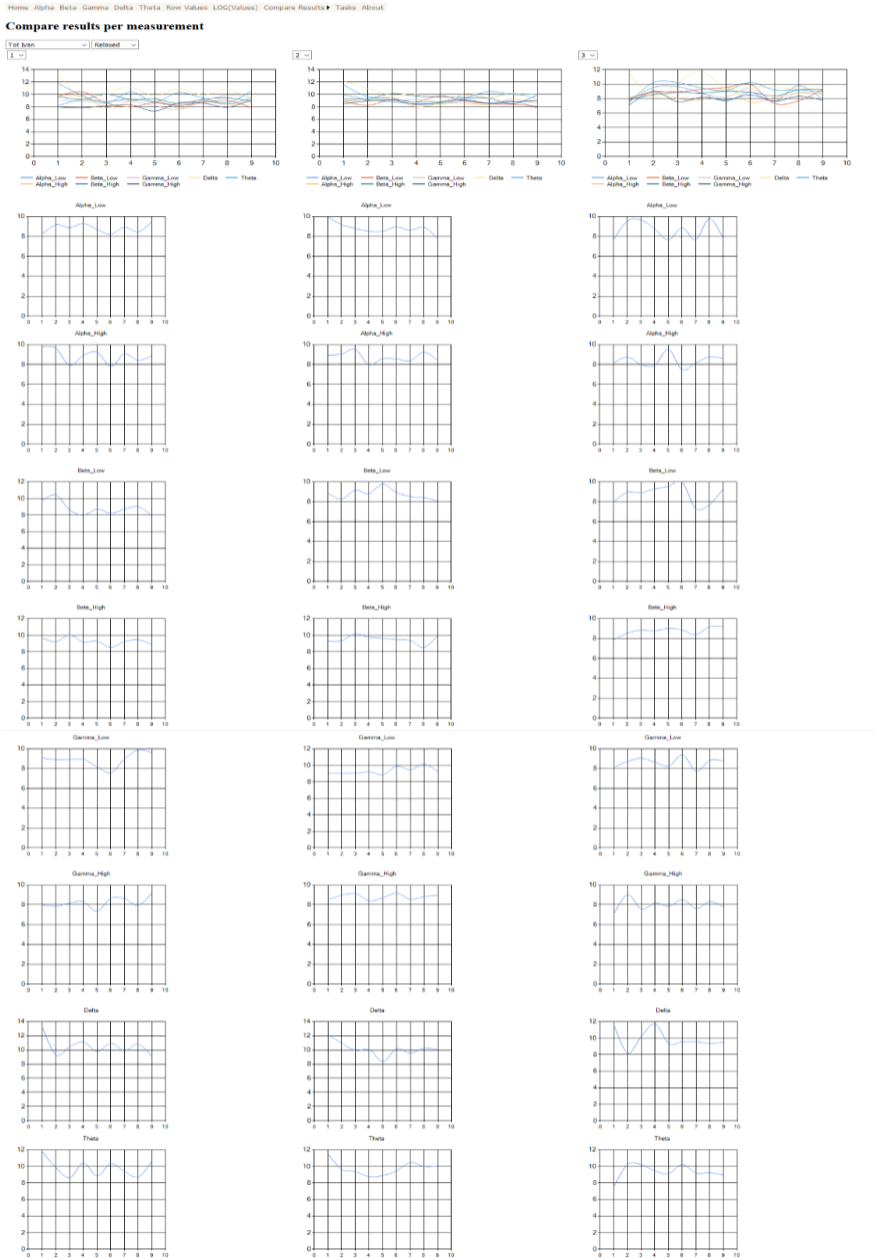


Figure 4
eIEEG web page for comparison of data per measurement

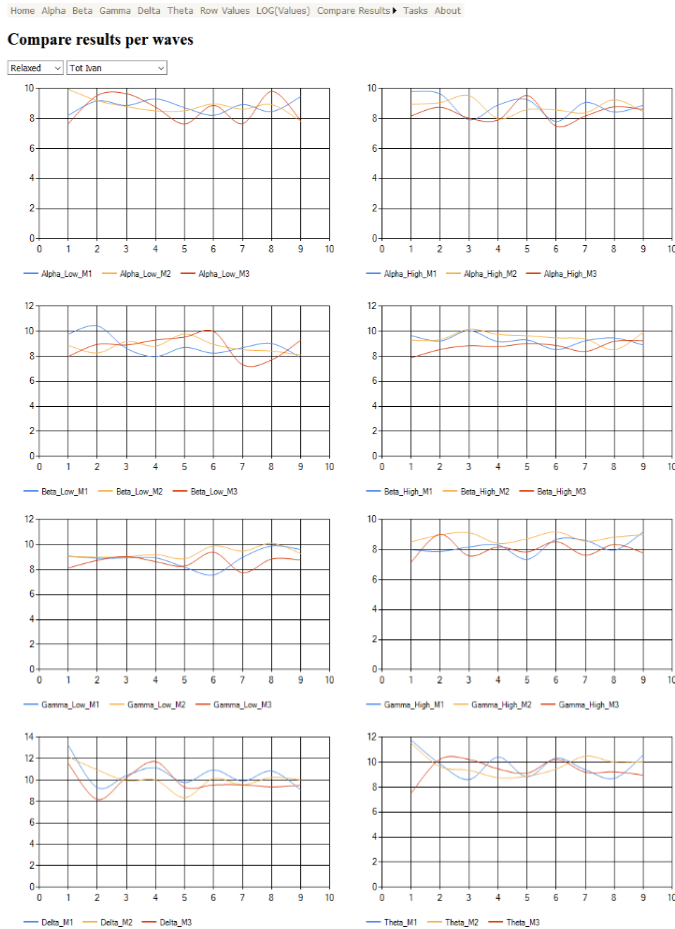


Figure 5

eIEEG web page for comparison of data per waves

4 Experimental Results and Discussion

In order to evaluate benefits of using the eIEEG platform, for learning about brain waves, we conducted research, in which, we compared two learning methods. The first method was traditional learning and the second was learning using the eIEEG platform. The main goal was to determine which method provided more improvements in efficiency of learning, better motivation and engagement of participants in learning process. The participants in this research were divided into

two groups – first, as a control group, which had traditional regular classes in classrooms and second, the experimental group, which used the eEEG platform as a tool for learning. Large number of participants in both groups had almost no previous knowledge about brain waves.

Each member of the experimental group had a computer with support platform installed and Neuro Sky Mind Wave 2-EEG device for capturing brain waves. A teacher was present but his only role was to guide participants through the process. They firstly used eEEG platform to learn about different types of brain waves. Secondly, they used eEEG brain wave data acquisition application to practically capture brain waves. Finally, they used the platform to compare captured brain waves.

At this stage of the research, three measurements, of all tests during different days are done, with the 60 participants of the experimental group. Structure of participants by their level of education, gender and number of years is shown in Tables 1, 2 and 3.

Table 1

Structure of participants by level of education

Education level	Number
High School	2
Faculty student	27
Bachelor	17
Master	9
PhD	5
TOTAL	60

Table 2

Structure of participants by gender

Gender	Education level	Number
Female	High School	1
Female	Faculty student	11
Female	Bachelor	1
Female	Master	1
Female	PhD	2
TOTAL (female)		16
Male	High School	1
Male	Faculty student	16
Male	Bachelor	16
Male	Master	8
Male	PhD	3
TOTAL (male)		44

Table 3
Structure of participants by years

20 to 30 years	31 to 40 years	41 to 50 years
12 female	2 female	2 female
29 male	7 male	8 male
Total: 41	Total: 9	Total: 10

The control group consisted of similar number of participants, with similar structure. They had traditional lessons with slide show presentations lectured by a teacher and possibility to ask questions.

After each lesson the participants of both groups took a knowledge test which consisted of 20 questions and 5 practical problems. Each correctly answered question was graded with one point, while each solved problem was graded with two points. Unanswered questions and unsolved practical problems were not considered. Figure 6 presents average knowledge test results. As shown on Figure 6, there was a significant difference between the groups regarding the practical problems.

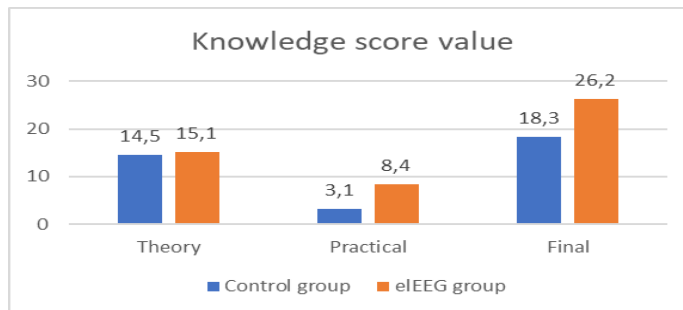


Figure 6
Average knowledge test scores

Upon finishing the knowledge tests, all participants filled in a questionnaire which included five questions related to motivational factors and 15 questions regarding the learning experience. All of them were based on principle of Likert scale [26] with the range of values from one to seven.

Figure 7 shows average scores to answers referring to learning experience. It can be concluded that the group which used the eEEG platform evaluated learning experience better. Significant difference can be seen in participant's experience that there is no theory and practice bond, there is too much information present and what is learned is valuable.

Figure 8 shows average level of agreement with statements regarding participants' motivation when learning about brain waves in one of tested ways. The results show that participants are more motivated when learning about brain ways by using the eEEG platform.

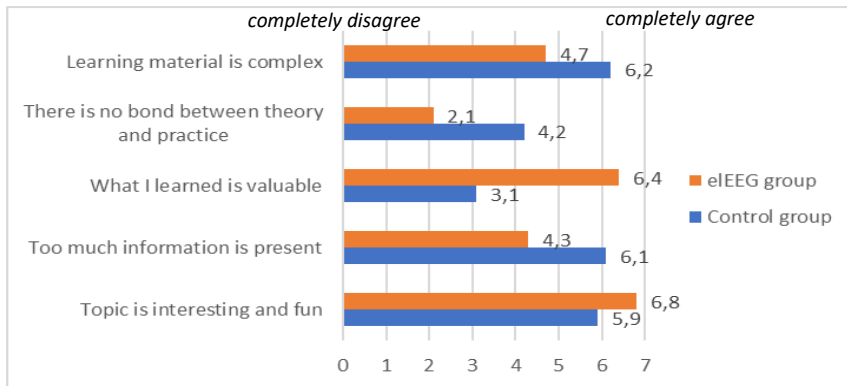


Figure 7
Learning experience average scores

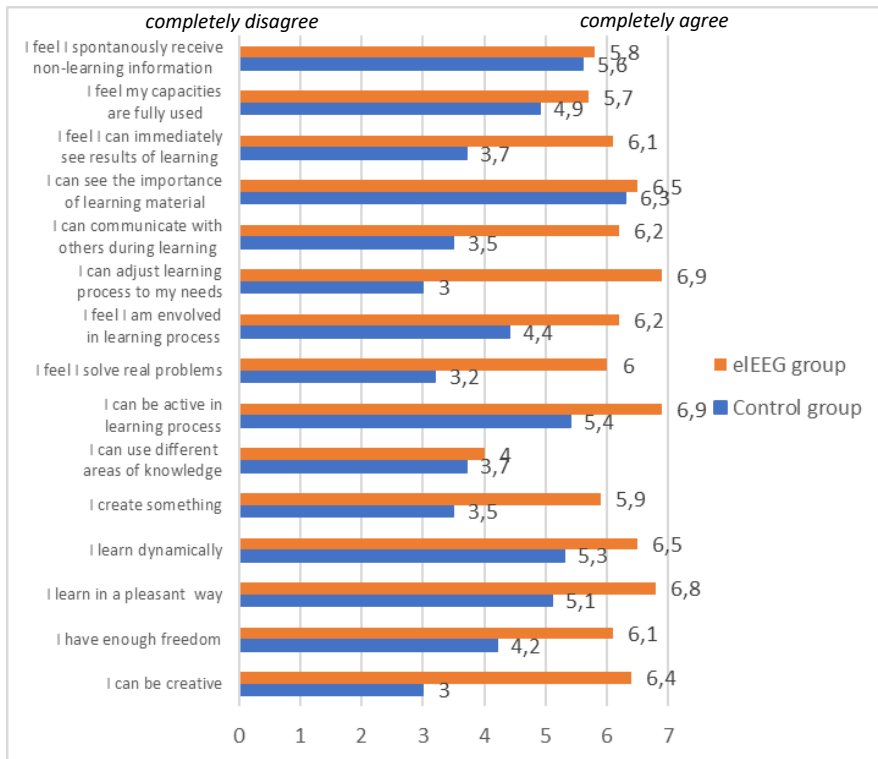


Figure 8
Average values of participants' learning motivation

Conclusions

The security of information systems is one of the most current and relevant issues of our time. Access control is particularly important, since it serves to block users, who do not have the right to access and use the system. Access by undesirable users, is very dangerous, because of the great possibility of abusing the system and the information that it contains.

The development of biometric systems and biometric sensors contributes to better protection through identity recognition and minimizes the possibility of abuse. Biometric technologies possess a great potential to improve system security and precision. The application of biometric systems improves the user's safety and also provides a much higher accuracy in identifying an operators identity.

Due to the importance of identifying users, it is necessary to constantly work on improving the system for precise proof of identity, that is, to improve performance, either through the development of biometric sensors, or through the improvement of the acquisition methods of biometric data. One of the potential ways is the use of brainwaves to authenticate users.

The basic idea of the whole project is to determine if there is a correlation of brain waves to the appropriate type of test for each subject, which could then be used to authenticate an operator. In the database, kept on a protected computer network, the images of the brainwaves of each user would be stored. When logging into the system, the real-time, measured brainwaves, of the user, would be compared with the recorded brainwave of user in the database. If there is a sufficiently high percentage of brain wave pattern matching, the authentication process would be considered, successfully completed.

So far, two applications have been developed in this project. One for acquiring sensor data and the other for visualizing that data.

In further research, a detailed analysis of the obtained data is planned, using different software packages and statistical tools to determine the correlation of brain waves, to the appropriate type of test, as well as, testing a significantly larger number of participants. This can only improve the accuracy if ID verification. When correlation is confirmed, brain waves could be used, reliably, to authenticate users.

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