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COGNITIVE ACTIVITY IN THE RESPECT OF QEEG RESEARCH - PRESENTATION OF LABORATORY TESTS

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Abstract. *The article presents the methodology of laboratory tests carried out in the Laboratory of Experimental Research Biofeedback of the Jan Dlugosz University in Czestochowa (Poland) regarding the evaluation of education effectiveness by registering brain wave activity using electroencephalographic research (EEG method). The research results indicate that, depending on the form of the computer program visualization, a change in the activity of SMR, Beta1, Beta2 and Gamma waves was observed. The results are presented in the form of graphs and 2D brain activity images using the equipment Mitsar EEG 202 and WinEEG software.*
Keywords: *teaching, effectiveness of education, modern teaching aids, cognitive process, EEG.*

Introduction

The use of measuring equipment for registering activity of the human brain can be a source of highly important data for determining the level of engagement and motivation in the process of learning. Results obtained in research conducted within cognitive science provide useful input for the domain of neurodidactics. For example, promising results were obtained in previous studies (Prauzner, 2016-18). This paper presents findings concerning the effectiveness of learning using deterministic computer simulations in technical university education.

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Discussion

QEEG tests are time consuming and because of that the number of testees is usually limited. However, in the interest of statistical validity of the results, efforts were made to make the groups representative enough and all students who volunteered to participate in laboratory tests were included (Prauzner, 2018b). In this way, 86 students participated in the study conducted in the academic year 2018/19, recruited from various academic disciplines represented at Jan Długosz University in Częstochowa and Częstochowa University of Technology (Ptak, 2015, 2016). For each group computer programs were prepared corresponding to the academic interests of the testees. Besides, for the sake of the study the programs were divided into categories (stages) with similar elements. The main criteria for distinguishing the categories (stages) were independent variables corresponding to the general complication and specific difficulties in their use, such as advanced command panel and tools (Tab.1). Cognitive activity is understood here as a process comprising such components as thoughts, sensory processes and perception. Examining cognitive activity by means of the QEEG method tests general engagement of the whole cognitive system in a number of processes enumerated in the literature. Recording signals by the EEG equipment provides information on how an individual is engaged in the process of task solving.

Methodology

The objective of the study is to find out if, and possibly to what extent, the organization and functionality of user's interface in simulation programs affects the user's cognitive activity. Examining the cognitive activity, in turn, will make it possible to assess a student's motivation and engagement in the process of learning, which translates into the effectiveness of educational tasks based on deterministic computer simulations. The main hypothesis to be verified is the claim that the presentation format, visualization, and ease of use of the interface significantly affect the user's cognitive activity.

The independent variable in the study is computer software of various characteristics, following from the construction algorithm applied, such as type of communication by means of menu written in Polish or in English, intuitiveness of the interface related to the number of graphic icons (simple or complex graphic menu), the format of the presentation of the model depending on the assumed method of solving the task (e.g. construct, correct, modify the model, find error in the simulation model) (Fig.1). The dependent variable is the cognitive activity determined by means of quantitative indicators obtained on the basis of QEEG tests in the consecutive stages of work and overt observation of the student's work. The study was conducted in a biofeedback lab and they involved recording the brain activity by means of the equipment Mitsar EEG 202 and software WinEEG (Tab.1).

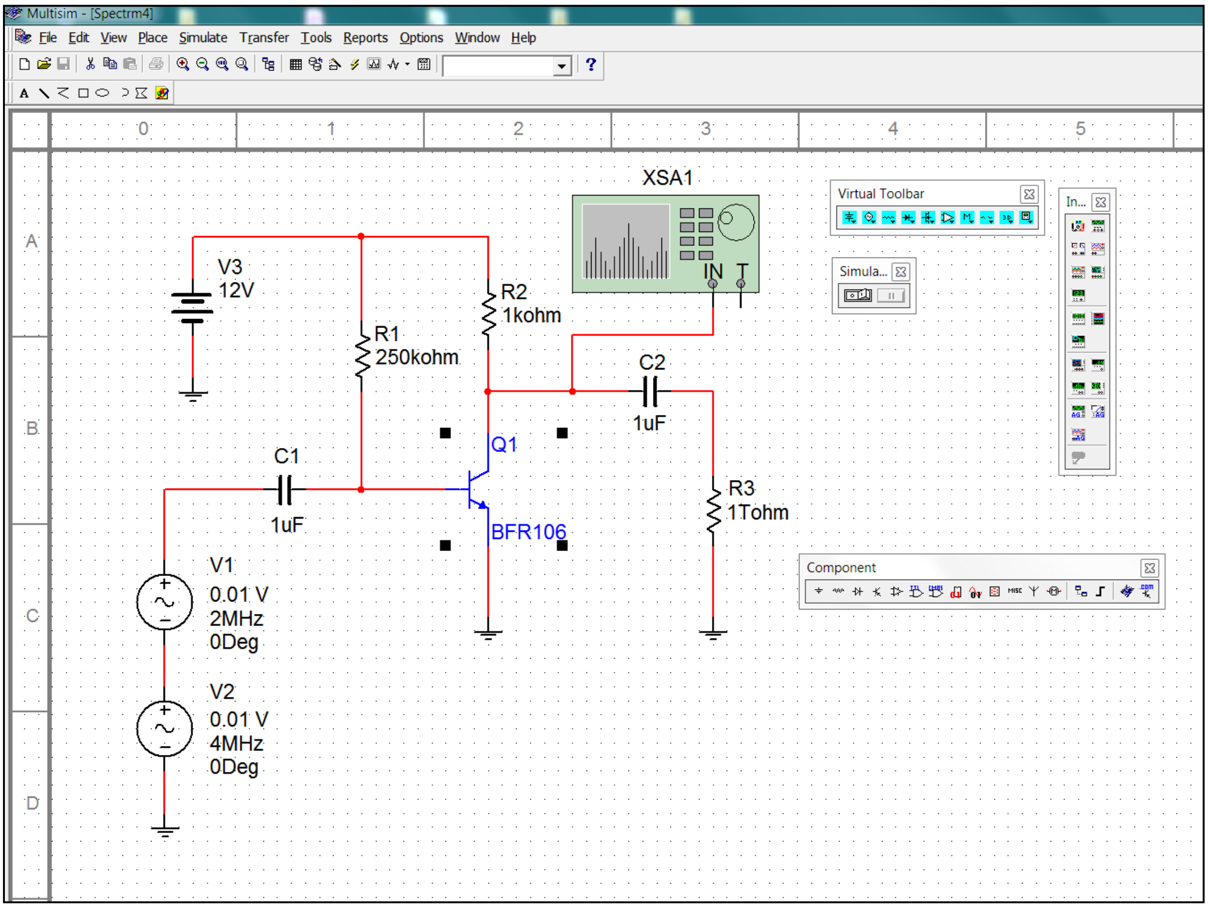

Figure 1 ***The example of UI in software***

Table 1 ***Stages of QEEG testing***

Stage	**Description**
I	Recording of an artifact caused by moving a mouse with a hand. This artifact was recorded for each participant and subsequently removed from the recording at every stage. Each participant's characteristic behavior with the computer was monitored.
II	Recording of the brain activity during the work with the simulation software, in which the menu is visualized as graphic icons, the meaning and functions of which are not easy to comprehend, with the menu and submenu written in English.
III	Working with software with an advanced graphic interface the interpretation of which is not intuitive, the submenu written in Polish.
IV	Working with software with an advanced graphic interface, the interpretation of which is not intuitive; the submenu written in English. To solve the task, it is necessary to read messages displayed in English, which provide clues how to use the menu icons, but these clues do not fully inform the user about the icons'

	functionality and purpose. Because of this, to be able to work with the software effectively, the user has to have good command of English and prior knowledge of the graphic menu. Due to their ample functionality and potential uses, this group of programs can be classified as professional software, yet they pose the greatest difficulties for users.
V	Working with software with an advanced graphic interface, the interpretation of which is user-friendly and intuitive; the submenu written in English.
VI	Working with software with an interesting 3D animation; the graphic is simple and shows prompts as complete formulas, the operating principle involves matching elements of a logical system. The user has to intuitively match elements of the 3D image, every step performed correctly is signaled as correct and every error is returned together with an explanation in Polish why this error was made and what it involved.
VII	Working with software characterized by a limited functional graphic menu. Solving a task requires using visualizations of real elements of the system (i.e. photographs of objects), the work is intuitive and the task fairly uncomplicated thanks to the visualization, which helps the user to choose the next step, and a limited number of graphic elements. The menu is limited to providing clues, obtained by pressing the right arrow key, even though the menu is in English, it is practically not necessary. A correct execution of a command is signaled by simulation of the system's correct operation and a short message.
VIII	Working with a simulation program showing a complete advanced complex model; the operation is however flawed by an unidentified error intentionally planted by the author. The aim of the work is to identify the error and to introduce modifications by changing some parameters of the program. Correct steps are signaled by a verbal message, simulation of the work and possibility to move to the next stage of the task. Solving gradable difficulties by proceeding from general to detailed elements encourages the user to analyze the system's operation in depth. The program is in English, with a very simple menu, using only basic vocabulary characteristic of most computer software.

Results of Research

The QEEG method is not precise in establishing the location of the source of a signal, since the waves are detected by a finite number of electrodes. Besides, other factors such as differences in brain structure, differences in skin impedance or stochastic factors can also affect measurements. A sensor detects a signal from a given area but this signal may result from the activity of various parts of the nervous system (Fig.2). Despite several disadvantages, one important advantage of the EEG method is that it is not-invasive. Besides, important study materials were obtained from direct observation. Due to a relatively large number of testees, the results obtained were systematized on the basis of similarities and differences between groups of participants.

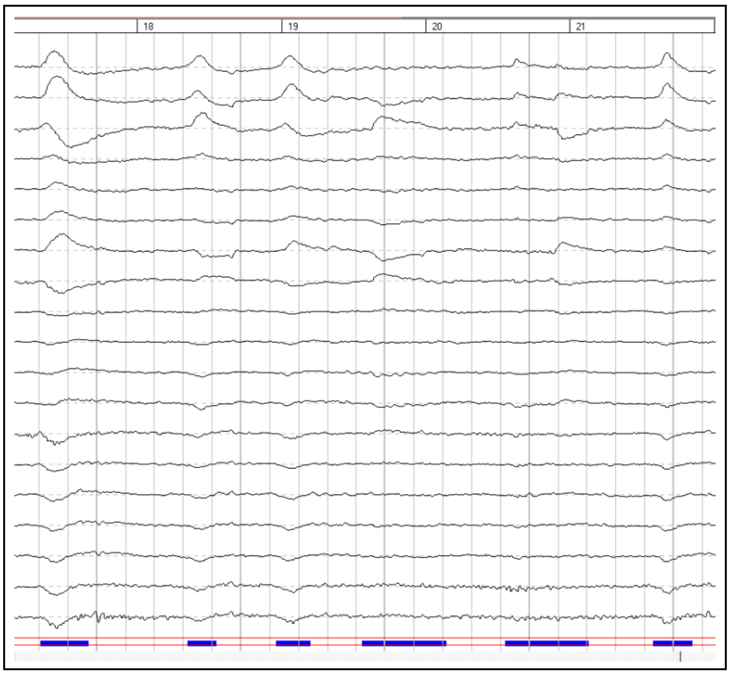

Figure 2 ***Artefacts removed from the recording (the blue colour) induced by the movement of the hand with a mouse***

In accordance with previous research (Prauzner, 2018b) the following cerebral wave frequencies were the subject of the study: SMR, Beta1, Beta2 and Gamma.

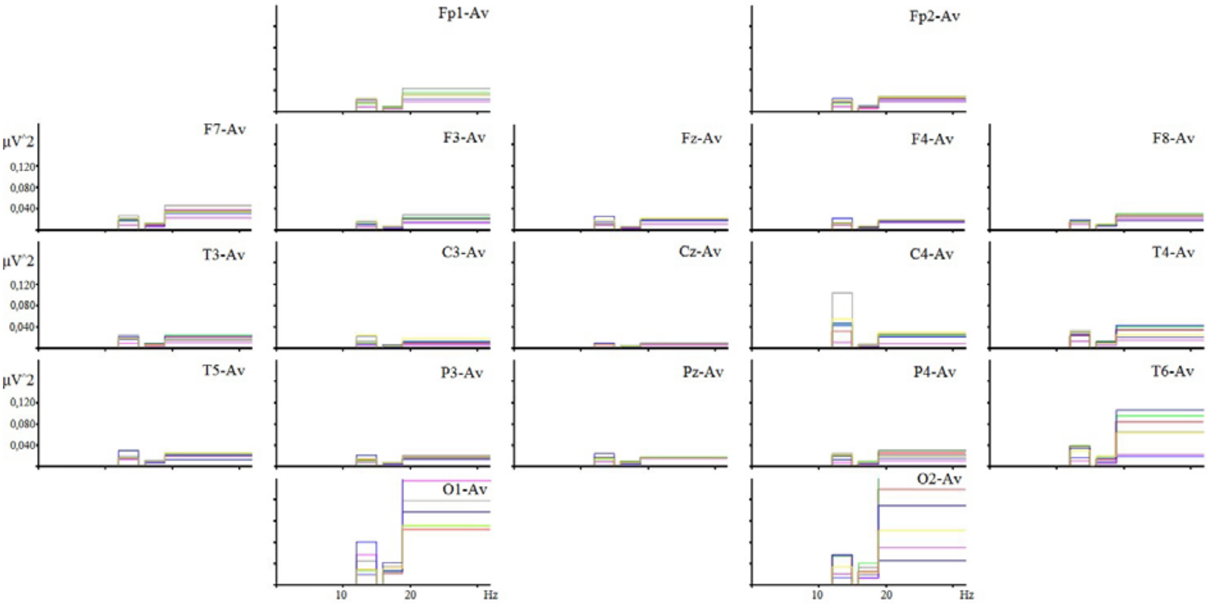

Figure 3 ***Power of the signal for the above-mentioned waves*** *(the red line stage II, the green line stage III, the blue line stage IV, the pink line stage V, the grey line stage VI, the dark blue line stage VII, the yellow line stage VIII)*

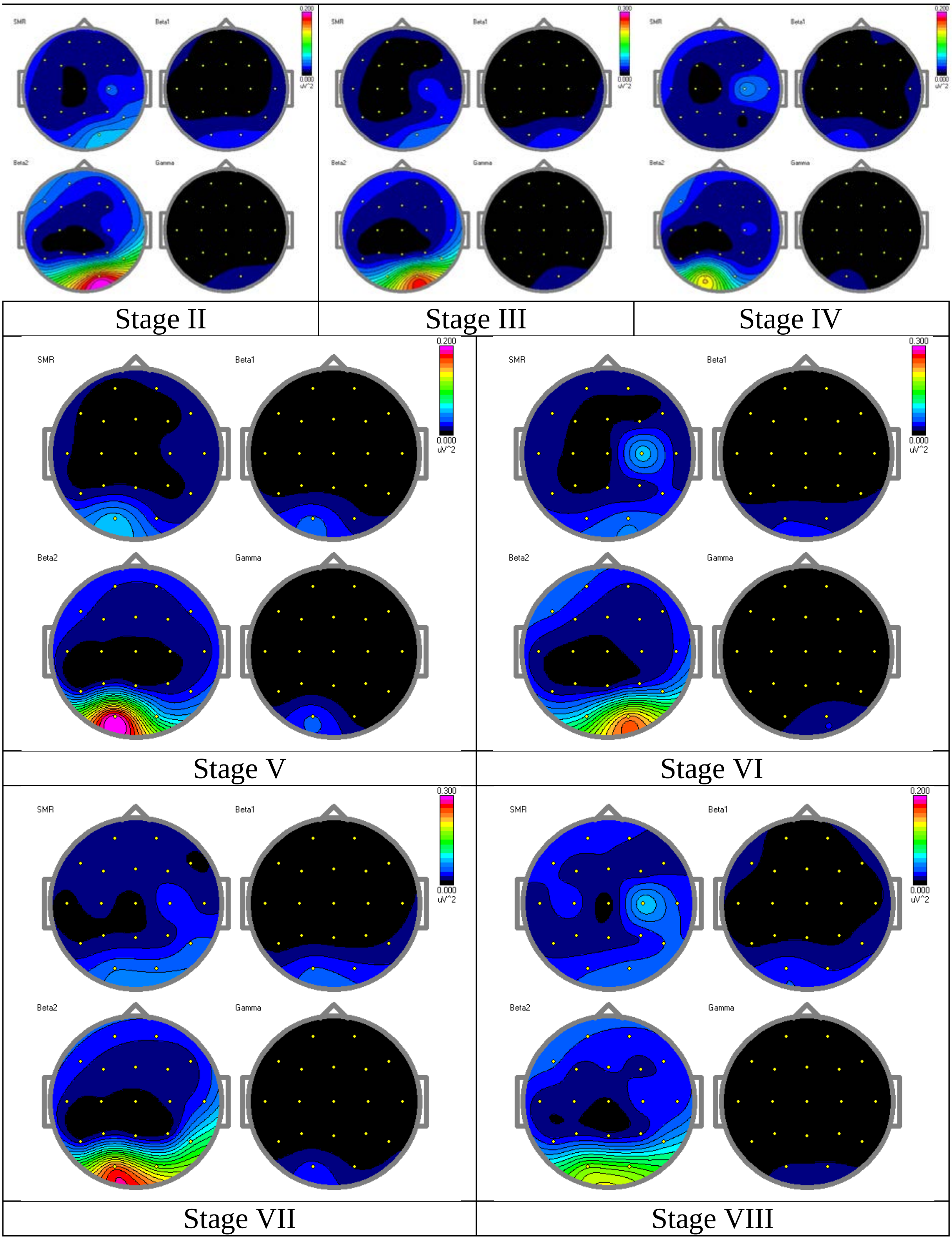

Figure 4 ***Graphic interpretation of identifying a source area of cerebral waves by means of the QEEG technique (an example),*** *(upper left - SMR wave; upper right - Beta1 wave; down left - Beta2 wave; down right - Gamma wave).*

Concluding remarks

The visualization of the brain activity indicates that the most active cerebral part were the areas of the occipital lobe and the parietal lobe and also, to a lesser extent, the temporal lobe (Fig.4). A change in the activity of cerebral waves, visible as frequency of oscillations, accompanies a change of the brain activity. According to previous studies, it is the brain areas mentioned above that are mainly responsible for processing visual stimuli. The occipital lobe analyzes such elements of images as color, movement, shape, depth, visual sensations and associations; it also interprets visual stimuli and makes inferences about them. The activity of the occipital lobe manifests itself in tasks requiring imagination and retrieving visual objects from memory and in tasks involving visual attention and visual associations. The right lower part of the parietal lobe is responsible for working memory, spatial orientation, imagination and visual sensations. The middle part takes part in processing symbolic representations, as well as abstract and geometrical concepts. When no activity is recorded in this area of the brain, it may be evidence of difficulties with drawing or with creating visual representations of objects. Processing a number of bits of information simultaneously, the right hemisphere of the parietal lobe is responsible for imagination, complex thought processes, and intuition. It is therefore dominant in intellectual activities. As neuroimaging tests indicate, the parietal lobe is active in tasks requiring not only attention, perception, spatial imagination, retrieval of information from memory, but also training skills connected with procedural memory (Wójcik, 2018).

All the results obtained in tests were grouped according to similarity. Fig. 3 presents a typical example of brain activity recording, obtained for the majority of testees. As the analysis of the results indicates, at each stage of the test all the Beta waves were recorded, with the wave Beta2 (or High Beta) being dominant in the occipital lobe. The highest values of this wave occurred at the second and fifth stage of the experiment and the lowest at the eight stage. SMR appeared in the right hemisphere in the parietal lobe and in the frontal lobe. The results obtained for a given observation may not be however sufficient to interpret unambiguously the character of the brain activity. For instance, analyzing the graphic results of the recording it is difficult to establish whether the recorded activity results from getting engaged in creative task solving or it merely results from coping with problems with using the software. It is possible to arrive at a more accurate interpretation by analyzing changes in the particular wave frequencies during the whole experiment. The dominant wave Beta2 occurs continuously during the experiment, but it is known to accompany intensive mental work. It is connected with high emotional stress, as it is responsible for adrenaline secretion when an organism gets ready to perform an action. It may also be a symptom of nervous and emotional excitation, fear or anxiety. In this experiment, the presence of this wave seems to be a natural sign of cerebral activity, since each of the computer programs is a new working environment, possibly perceived as a challenge by a user. Getting to know the application without a prior instruction or practice naturally leads to the user's anxiety. Detailed analyses carried out for particular stages of the experiment shed more light on the results (Fig. 5, 6). As can be observed, for instance during the fourth stage of the experiment, the wave Beta1 appears, which indicates engagement in task solving.

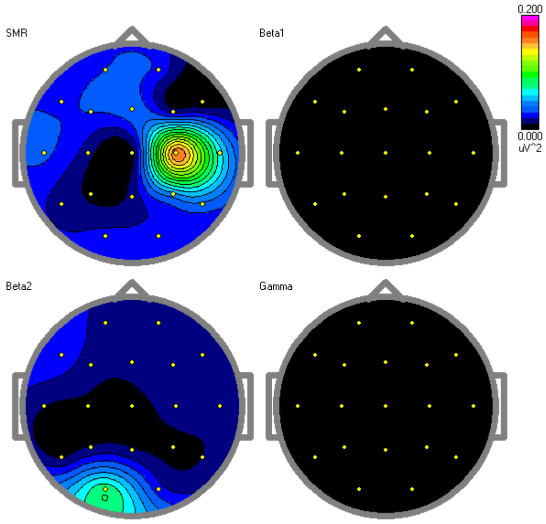

Figure 5 ***Beginning of Stage IV***

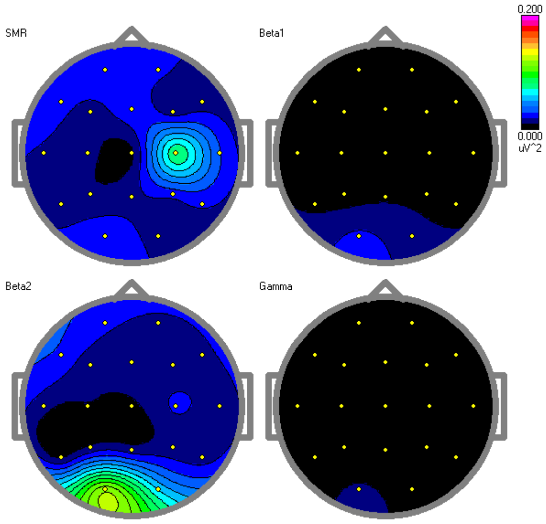

Figure 6 ***End of Stage IV***

A similar effect was observed during the other stages of the experiment. The wave Beta1 appears with varying intensity, but the differences are not sufficiently significant to support any specific conclusions on effectiveness of a given type of application. Here direct observation provides more accurate additional data. It can be thus stated that non-intuitive graphic interface and using a foreign language are a serious obstacle in using the program. The main problem to be solved is to master the ability to use the software and the working environment can become a discouraging factor for undertaking any further activities. The tests carried out by means of the QEEG technique indicate that simulation software is an environment in which human beings display high-level mental engagement. Even though it was of comparable magnitude at all the stages of the experiment, the reasons behind its occurrence were different. The testees tried to familiarize themselves with new tools as fast as they could, but depending on the software and its interface, the task was more or less demanding, especially at the initial stage of work. The simpler and more intuitive programs, in which the interpretation of graphic and verbal messages was faster, took much less time to master. This is especially important considering the fact that the classroom time is limited. Computer programs which are very complex or expanded are therefore less useful for didactic purposes, as they extend the time of work spent on a task. They may have advantages from the standpoint of their computational potential, indispensable to perform scientific tasks, but they are not always the optimum choice for teaching. A QEEG can identify not only brainwaves, their amplitude, location and whether these patterns are typical or anomalous, but also coherence (quality of communication between regions), phase (thinking speed), and network integration. The EEG and the derived QEEG information can be interpreted and used by experts as a clinical tool to evaluate brain function, and to track the changes in brain function. Research results indicate complex brain activity during learning. It is an extremely complex and dynamic process, because learning using a computer is associated not only with the continuous observation of the computer screen (simple cognitive processes), but also with constantly complex cognitive processes adequate to the difficulty of solving the task. Therefore, the obtained results are only preliminary research, which in the future will be used for further detailed research. The maximum volume of the article limits precise considerations on a given subject, nevertheless it sets a new direction of research on the use of modern teaching aids in education.

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