

Examination and comparison of the EEG based Attention Test with CPT and T.O.V.A.

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Abstract— Attention as a focusing and concentrating ability have great importance in doing daily tasks precisely and adequately; furthermore, it is a significant factor in the learning process. In this paper, besides some attention and concentration measuring methods, an innovative EEG-based measuring and examination technique of continuous attention will be demonstrated. The results of these different methods have been compared and evaluated in this research. The most significant advantage of the EEG-based attention measuring method is the possibility of time continuous examination that can shortly provide information about the actual mental state of the test subject. This information can be useful in teaching and applying the most convenient method of sharing and acquiring knowledge; therefore, it can virtually improve the result of learning.

I. INTRODUCTION

Attention has an important role in doing our daily tasks properly and it is a great importance in the process of learning and memorising. According to the definition of attention, it is a partly cognitive process that starts to operate when environmental stimuli are perceived in which concentration is selectively focused on some aspects of the environment only, so it can be defined as the concentration on important information. It also determines what we can subsequently remember. [1, 2]

Attention as a concentrating ability is responsible for emphasizing the point in the received new information and through this, it also plays an important role in the memorising process. Besides the understanding, analysing and problem solving abilities, effective and successful learning is also determined by the cognitive abilities of attention and memory that also depend on emotional and motivational conditions. [2, 3]

Human learning, the brain procession of information and knowledge transmitted by different stimuli, can be examined as a complex system. In cognitive psychology, the information processing model of Atkinson and Schiffman also reveals the significance of attention in this complex information processing. [4] The strength of attention and focusing, or the emphasizing function of new information is also important in long-term memorising.

During learning, the human brain can be examined as a system, in which the changes remain for a long time. The adaptive change in the brain, the change in the operation of the system means the transformation of the network formed by the connections of brain cells and it results in better human functions. [3, 4]

Numerous methods have been developed to examine attention, of which the computer-based examinations are widely applied, for instance the Continuous Performance

Test (CPT) and the Test of Attentional Vigilance (T. O. A. V.). [5, 6]

However, more advanced examination methods are used in cognitive neuroscience. The development of these techniques are facilitated by devices, such as the functional magnetic resonance imaging (fMRI), positron emission tomography (PET), transcranial magnetic stimulation (TMS), near infrared spectroscopy (NIRS), or electroencephalography (EEG). The results of these examinations help researchers realize what happens in the brain during learning and make them able to develop new methods to provide better learning results. [7]

In the past few years, cheap and mobile EEG-based signal processing devices have become available and result of these the electric signals generated in the brain can be measured and processed in real time. The evaluation of information determined by the spectrum of brain signals ensures the examination of the mental state of the brain and the extent of attention or concentration, which are both important in learning. These innovative examination methods can result in applications of new research areas.

II. THE COMPUTER-BASED METHODS IN ATTENTION EXAMINATION

In this chapter, some attention level measuring and examining methods will be described, which reflect the concentrating ability on given stimuli in the actual mental state of the test subject. For example, Conner's Continuous Performance Test (CPT) or the Test of Variables of Attention (T. O. V. A.) tests are applied in several other research to measure the level of attention. [5, 6, 8, 9]

A. The Continuous Performance Test (CPT)

In the Conner's Continuous Performance Test (CPT) a simple examination technique is applied: the test subject has to react in case a rare signal appears. The method is described in the study of Rosvold and Mirsky. [6] The test approximately takes fourteen minutes to finish and observes the level of attention. During the most commonly used CPT, 360 letters are shown the respondents and they are instructed to indicate if any letter appears, except the letter "X". The test can easily implemented on a computer program, in which the algorithm random generates a letter on the screen in 18 character visualizing blocks in every 1, 2, or 4 seconds for 250 milliseconds. If the letter is not an "X", the respondent has to press the spacebar. After each block, breaks are allowed and the test can be continued by pressing any key. The number of mistakes and correct answers as well as the reaction time report can refer to the attention level of the test subject. [8, 9]

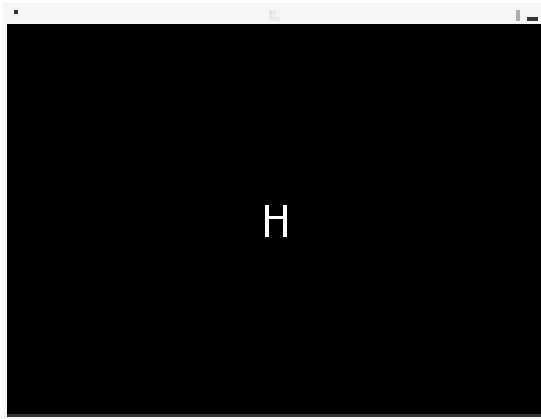


Figure 1. The Continuous Performance Test (CPT)

B. The Test of Attentional Vigilance (TOAV)

The test of variables attention (T. O. V. A.) is an objective neuropsychological assessment of attention. It is a 21.6-minute-long test that is presented as a very simple computer game in which the response of the test subjects to a visual or auditory stimulus is measured. [10] The T. O. V. A. test can be widely applied, both for clinical and screening functions. The clinical version is primarily used by psychologists or neurologists to diagnose attention disorder, while the screening version of the test is used by school professionals or in rehabilitation programs. The test provides immediate simple processable reports; moreover, it is language and culture independent and measures reaction time precisely. A simple implementation of the T. O. V. A. test is the T. O. A. V. attention / vigilance test, which only measures reaction to visual stimuli. On the screen of the computer, a black square can be seen randomly either in the upper part or the lower part of a white square. The test takers are instructed to press the spacebar, only when the black square is in the upper part. [5, 9, 10]

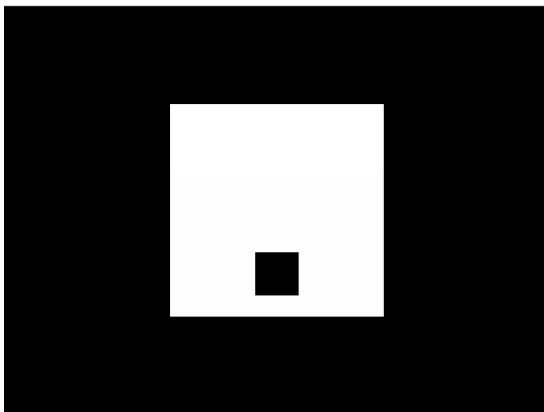


Figure 2. T.O.V.A. test

III. THE EEG BASED ATTENTION MEASUREMENT

The test-based attention examination methods can be used to measure attention while doing a certain test. However, to measure the concentration of a test subject on other external stimuli instead of measuring attention while doing a test, the previously introduced tests are not applicable. The extent of attention, resulting from the external audio-visual stimuli that affects students whilst learning, cannot be examined either. Therefore, an

attention measuring method that can examine concentration induced by arbitrary stimuli has to be applied instead of the test-based attention measurement techniques.

The activity of the brain during attention can be observed with innovative measuring techniques applied in cognitive neuro science. For instance, fMRI, PET, TMS, NIRS, or EEG. The first four methods are quite expensive, difficult and involve a hardly wearable measuring device, while cheap and mobile EEG-based devices are available commercially. With sensors placed on the scalp, the electric brain activity can be observed with EEG devices and the different mental state of the brain can be concluded from the results. The connections between the brain waves that are determined from the mental state of the brain and the spectrum of the observed signals of the electric activity of the brain are well-known. Brain waves are distinguished according to their frequency range and are called alpha, beta, gamma, delta and theta waves. [11] For example, the frequency range of delta waves is lower than 4 Hz, and it is actually the state of deep sleep. The frequency range of theta waves are between 4 and 8 Hz, while alpha waves are between 8 and 13 Hz that can be reached in calm state of mind. It is also known that certain areas of the frontal lobe are responsible for the operation of attention, vigilance, selective attention, continuous attention and orientation and it is of great importance in cognitive processes and thinking. [12]

The connection between attention and brain waves were already observed in the 1970s and an EEG-based analyser was patented. [13] The method of attention measurement is based on the determination of the strength of brain wave spectrum between 8 and 13 Hz electrical brain activity, which is implemented with a bandpass filter and determined by an FFT algorithm. This spectrum is actually the frequency range of the alpha waves, where the level of attention is low and the patient is calm. According to observations, with the increase of attention, the amplitude of brain waves in the range of 8 and 13 Hz is rather low in the frequency range of 0.5 and 50 Hz. [13] On the other hand, the amplitude of brain waves in the frequency range of 8 and 13 Hz in inattentive state is rather large. The operation of the attention analyser is also based on these facts. By applying a measuring system based on the measurement of brain waves, the learning process and the level of attention becomes measurable. This means that with the measurement of attention, the probable results of learning can be concluded. [13]

IV. THE MINDWAVE EEG-BASED DEVICE USED FOR ATTENTION MEASUREMENT

The MindWave EEG headset is not a new device and beside the fact that it is user-friendly, it is also simple to use, comfortable and applicable of further research. It applies wireless communication (not a standard WiFi or Bluetooth) and a dry type, passive sensor. The positions of sensors can be seen in Figure 3. It was originally designed to improve brain functions and abilities but nowadays it is widely used to improve learning and the quality of life. Its chip was developed by Neurosky based on ThinkGear technology and it determines the value of attention, meditation value, blinking and brain wave values in 0.5-50 Hz. Its power is provided by an AAA type battery. [14] (Fig. 3)

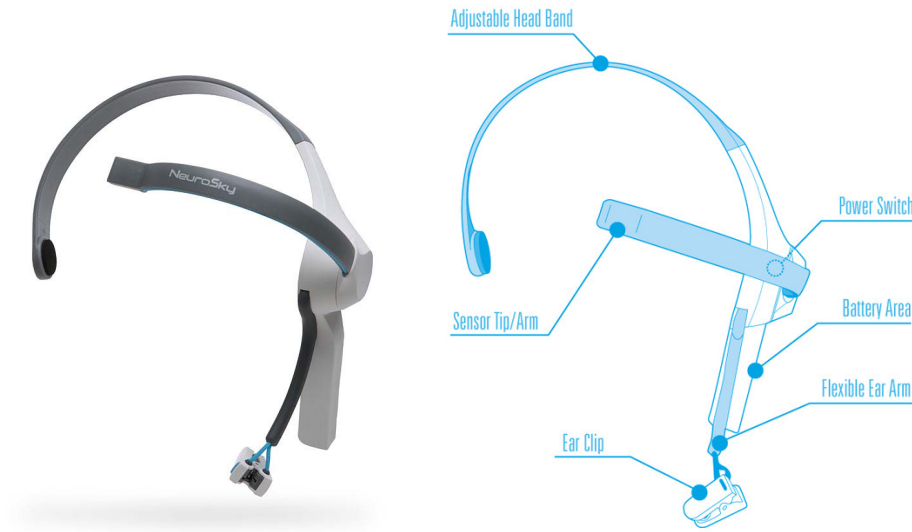


Figure 3. MindWave EEG headset

This device can measure the electric signals of brain activity with sensors located on the frontal lobe in comparison with the reference points connected on the ear. It can also determine the intensity of brain waves and the value of attention with the algorithm running on the built-in microcontroller. It can also process data in real time, which is also used in several data procession and control systems. [15, 16, 17]

V. THE COMPARISON OF METHODS FOR ASSESSING ATTENTION

The attention examination methods described above were tested by voluntary test subjects, the students of Rudas Economic Technical and Vocational School and Hostel aged between 14 and 18 in Dunaujvaros. Totally thirty-two students participated in the test: sixteen males and sixteen females. Six students were from ninth grade, twelve students from tenth grade, eight students from

eleventh grade and six students from twelfth grade at the time of the examination.

The CPT was applied at first which was followed by the TOAV. The value of average attention measured by the EEG headset was continuously evaluated while doing both tests. The temporal variables of the value of attention are shown in Figure 4. The results of the test are shown in Table I, including the average correct answers given to the target stimulus and the level of average attention determined by the BCI data processing system. The table below illustrates the value of attention measured by the EEG headset after the TOAV of a test subject. According to the results seen in the tables, it can be claimed that the values in a more vigilante state, larger attentional state measured by the applied attention examination methods are higher. Furthermore, the results of the tests done in tired state are worse, which fact is also confirmed by the lower attention level measured by the EEG.

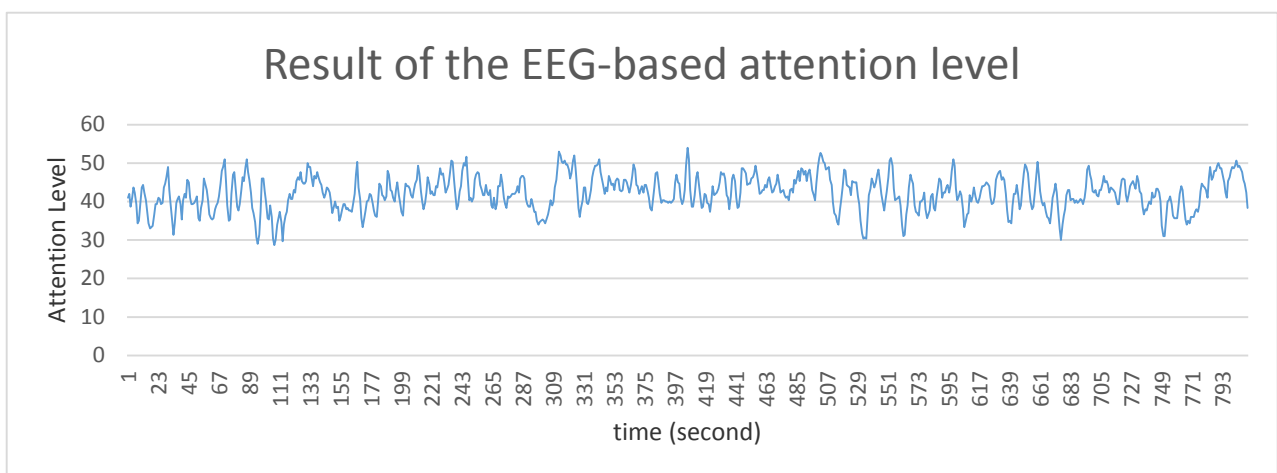


Figure 4. One of the results of the EEG-during the tests

TABLE I. RESULTS OF ATTENTION TESTS
TEST: A HIGH MENTAL STATE

Attention Tests	Total Trials	Average of Correct Trials	Average of Acc. Rate/Attention Level	Standard Deviation
CPT	324	319	98,5%	0,56
EEG			51,9%	3,67
TOAV	640	636	99,4%	0,49
EEG			52,6%	3,51

TABLE II. RESULTS OF ATTENTION TESTS
TEST B: LOW MENTAL STATE

Attention Tests	Total Trials	Average of Correct Trials	Average of Acc. Rate/Attention Level	Standard Deviation
CPT	324	309	95,4%	0,72
EEG			45,9%	3,81
TOAV	640	619	96,7%	0,67
EEG			46,3%	3,78

These different attention examination test methods can be applied as an alternative method for the examination of attention depending on the mental state of the test subject. The advantage of the EEG-based attention examination method is that it does not require a test task, it can continuously monitor the level of attention during an actual brain activity, for instance during the process of learning as well.

VI. CONCLUSIONS

In this paper, some attention examination methods have been described. The results of CPT and TOAV tests show that the level of attention was lower in test B compared to test A. The attention level decrease between test A and B is consonant with the results of the EEG-based attention examination method. It can be stated that the results of the different methods to measure attention are similar; therefore they are good alternatives to observe attention.

The applied attention measuring methods have been test-based so far, i.e. the answers given to the stimuli in the test were examined and evaluated. For real-time examination of attention, these test-based attention measuring methods are not applicable, though. In contrast, the EEG-based attention examination method ensures continuous examination in time, so continuous information can be gained about the actual mental state of the test subject. This information can be used in teaching to choose, modify the right knowledge sharing method or break, which could finally improve the results of learning. If attention becomes low, the information processing ability of the brain decreases as well and it negatively affects the procession of new information and connection besides memorising.

The change of attention level, the most important factor in learning, can be continuously measured, so the efficiency of learning can be continuously observed. This means that it can provide continuous feedback about the level of attention of students to the educator and it influences the efficiency of transferring knowledge. If the teacher sees that the attention level, or the efficiency of learning decreases, he / she can change teaching methods, use more interesting modes of teaching or even keep short breaks. As a result, the efficiency of learning and teaching can be greatly increased in the end.

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