Neural Interface: The potential of using cheap EEG devices for scientific purposes

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Abstract. Alternative input devices for computing have come to the forefront of interest of scientific teams. The idea of controlling the computer with mind has great potential. The popularization of this topic has led to a greater public interest and the creation of a market for cheap EEG devices. The article focuses on the evaluation of affordable EEG devices usage by scientific teams. Two different devices were used. The validation programs were created in the C# programming language. On a test sample composed of students, University staff and other suitably selected test subjects, the potential of affordable science devices was evaluated. In the conclusion of the article there is a discussion, as the device cannot be used for high-quality scientific work. The article also deals with the scientific teams that use the equipment for "serious" research and marks the specific errors and deficiencies that teams have committed and therefore may have the impression that the device is usable.

Keywords: EEG, alternative user interface, user interface, neural interface, Neurosky, brain, validation, effectivity.

1 Introduction

The current input devices used in information technologies were developed more than 50 years ago. Use of mouse and keyboard is very often effective - but this efficiency is usually built on the user's training. At present time, however, alternative input devices must be taken into account as well. In addition to resistive, optical and familiar touch devices, the use of EEG signals can be considered. The consequence of the EEG option would be to remove the intermediate level and control the computer through actual decisions of the user.

For a deeper understanding of the issue, it is necessary to understand the EEG principle, or the creation of human thoughts - so literature [1] and [2] are recommended. Consequently, it is desirable to understand the principle of capturing EEG signals [3], their processing in software, especially with emphasis on the application of the Fourier transform [4]. The article does not deal with the direct implementation and the source code samples are not part of the article. Knowledge of programming techniques is an advantage for the reader. For a better understanding of the case study, it is desirable to have a basic overview of the topics of representative sample production, case study and its evaluation. The used statistical apparatus is available, for example, in [5], using statistics of reliability, validity, obliquity, and punctuality. Verification of values was based on a good match test.

2 State of the art

Current experiments with the creation of bridge between mind and information technology can be tracked at several different levels. The key is the information technology loop - a person, where actual results are already very sophisticated and demonstrable. The fields of EEG signal research include primarily medicine - which focuses on the EEG as such and serves primarily for patient diagnosis. Information technology is being processed on a different level and uses different resources.

2.1 Influencing the mind through information technology

The basic link between the user and the computer, so that it can be influenced by the user's EEG can be achieved by means of frequent displacement methods. In fact, it is a simple method, used by, for example, the so called "psychowalkmans". Through the headphones, a 50 Hz frequency is transmitted to one of the user's ears, and 55 Hz to the second ear. The brain is gradually "tuned" to the inter-frequency - the two frequencies are actually deducted. Because the frequency of 5 Hz corresponds to Delta waves EEG, a man exposed to this effect falls asleep relatively quickly, as he tunes his brain to the Delta sleep waves. Indirectly, this influence of the mind can be observed, for example, in means of transport, such as a train, where gentle jiggles often manifest strongly. The ability to tune the brain to selected EEG frequencies is evidenced by studies [1].

2.2 Processing signals for medical purposes

Knowledge of EEG signals and their composition in various activities is a key way of diagnosing many diseases and brain disorders - epilepsy, Alzheimer's disease, post-stroke conditions and others. In the field of medicine, it is not crucial what particular waves mean specifically (e.g. "seeing the red colour"), but the key is the correct ratio of each class of brain waves. Especially when monitoring individual waves in the context of resting, normal activities or sleep, which makes human bodies very similar, it is relatively easy to find deviations from normal and diagnose diseases. See literature [3].

2.3 Advanced processing of EEG signal

From EEG signals, it is possible to track a number of other information besides the standard frequency representation of individual waves. In the last decade of the last century, the first experiment was developed to use EEG as a lie detector. The use of this principle was that the representation of the frequencies in the brain is different in the case of a man trying to remember and in case of making something up. The problem with this method was the fact that the tested person only had to prepare the lie in advance, and then remember it - the notorious liar then succeeded in the test.
The research itself, however, laid the foundations of a very sophisticated discipline, which seeks to find similar patterns in behaviour, but at a much more detailed level. The disadvantage of these methods, however, is, at present, that the results are always strictly individual. So, if any two people start thinking about the publisher Springer, the manifestation of this will in the EEG in each of them will be completely different. However, if these two people begin to think again about Springer, their own result (though among people unique) will match their own EEG formulas.

The abovementioned technique is very often abused in order to demonstrate the efficiency of the operation of EEG devices. The actual sophisticated formula for a particular publisher is sifted from about 50 different partial frequency bindings and is not easy to distinguish for a particular individual. It requires very precise equipment and very high computing power. However, this applies only when we distinguish one particular idea from another. The situation will change dramatically if we create a very limited set of ideas, such as "Springer", "Cow", "Sun", "Wet". If we have enough time and diagnostic data for individuals, it is not difficult to distinguish these ideas. In practice, such use is almost inapplicable because the experiment is built so that it cannot fail. This is the case for simplifying the baseline set of questions so that only two or three data sets can be tracked from the need to monitor 50 frequency occurrences. In addition, data no longer need to be tracked in the context of the entire brain (i.e., to search for a particular location). In a properly designed test, it is possible to demonstrate the functioning of any EEG device.

2.4 Sensor location and typology

To correctly understand the problematics, it is necessary to accentuate the different typology and placement of EEG device sensors. The most complicated is scanning a general field through an electromagnetic detector – magnetic resonance with deactivated actuating field. This solution is very expensive, and unusable in practice.
In practice (medical and general), electromagnetically-sensitive electrodes are commonly used. The accuracy of these electrodes is acceptable in the field of medicine (and others sciences as well), as any precision greater than 7 bits/value is considered acceptable.

A practical problem is the segmentation and complexity of the brain. Waves are defined not only be their shape, but also by the location where they emanate from, how they distribute etc. (that is how we can tell sleep riddled with nightmares from sleep with pleasant dreams). For this reason, electrode count and localization is crucial. The minimal number of needed electrodes is two. The problem with using two electrodes is that the location from where a wave propagates cannot be precisely determined. Most affordable EEG devices, including the one used in the case study, use only two electrodes. The result of using only two electrodes is evident; during the lie-detecting test, all the tested subjects had to do to simulate intensive thinking is think of breasts (although it may sound sexist, it has been scientifically proven that for males, breasts are a stimulus that alters the results the most).

High quality medical facilities, including the medical ones, have by European standards 10-20, where the numbers do not represent electrode count, but distances in percent from other electrodes in vertical and horizontal planes. Such a facility usually uses a minimum of 20 electrodes, distributed all over the scalp.

3 Case study

For the case study, several devices NeuroSky MindWave devices were used. No differences were found among these devices, and that is why they are discussed generally. The devices boast two electrodes, one of which is placed on an ear (grounding electrode) and the other in the middle of the forehead. The device looks like a headband. The NeuroSky company provides a program library thinkgear64.dll with and open interface, which allows further work in C#. The company admits that the device is capable of measuring two primary values, generally called “focus” and “relaxation”. The manufacturer was however not capable of identifying precisely what is measured, even after further questioning.

The actual case study is a collection of questions – a variant of a didactic test. However, before the actual case study is introduced, it must be noted that more application were made. During solution testing, a game called SnakeEEG was crated. This game aims to use the measured values to move a snake – a game very similar to the famous game of old Nokia phones. The second application that was created is called Space Adventure EEG – a simple space game controlled only by the values of focus and relaxation. It was discovered that it is possible to learn how to control applications through EEG signals. It is not possible to reach any other states (except for focus, meditation and nervousness). For basic game controls it is enough.

3.1 Case study

The actual case study took place at the University of Pardubice in spring of 2017. A total of 42 persons took part, with a variety of students, faculty staff and public. Pictures used along with questions can be seen in Figure no. 1.

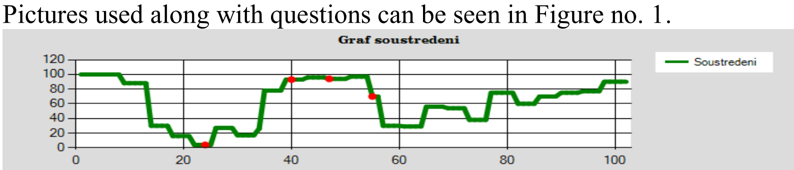

Figure 1: Test result graph

The following questions were asked:

a. How many windows does the house have?
b. Solve the equation.
c. What colour is the model's underwear?
d. How many triangles are in the picture?
e. Find 6 differences between the two pictures.

During the process, the user was wearing an EEG headband, and the EEG activity of the user was tracked. Illustration of activity can be seen in Figure no. 2.

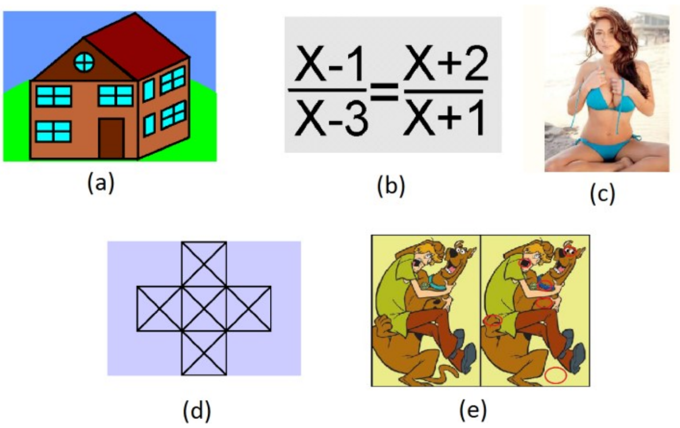

Figure 2: Questions of the validation test

The graph's X axis represents time, Y axis represents focus. The moment the question is asked is marked by a point on the focus line. In the depicted example, we can see that the focus levels correspond to the difficulty of the questions. The focus levels are quite high when solving the most difficult question. On the other hand, the underwear question lowers the focus level to minimal values, and has a lasting effect. Following values are typical of a person solving logical problems.

The Figure shows fluctuations of focus levels for various questions. However, common patterns can be found. Especially with the question about the colour of the model's underwear, male subjects showed a significant drop in focus level, and took almost 10x the time to answer than female subjects. Generally, it can be said that the test was a success, and it was proven that the device can be used for focus level tracking. However, it is important to note that other factors and external influences, e.g. distracting the subject, has a significant influence on the whole measurement.

3.2 Discussion

On the basis of executed experiments and three application, some results may be drawn. The first conclusion is thought distinction – although changes of focus level are generally dependent on mental activity and the presumptions of this process may be generalized, it is simple to bias the measurements. Bias errors can be introduced through external influences (acoustic interference, or even strong eye contact with the testing subject), or through internal influences (instead of solving the question at hand, it is possible to think intensively about any other topic). Measurements done with only one electrode (and grounding) are ineffective.

Hypotheses stated in for example [6] or [7] which point out the risks of spying passwords through EEG interfaces are, as of today, exaggerated and pointless. Without the complex knowledge of the user's behaviour patterns and his complete EEG image, such spying ruled out.

The theory stated in [6] and similar expert articles can be qualified as very precise experiments, the environment of which is controlled so strictly that results other than positive were not possible.

4 Conclusion

The contemporary marked is highly saturated with simple devices with two, four or eight electrodes. These devices were tested during the research part, and the results will be follow. The price of these devices is in the range of tens to hundreds of dollars. They can often be connected to mobile devices or computers, and are supposed to help with concentration.

Price of high-quality medical-gra de devices moves in the thousands of euros, high-quality devices with professional software can cost up to hundreds of thousands of euros.

In our research, it was discovered that the prices are not pointlessly exaggerated. Affordable devices with few electrodes and sub-par quality level of the software (which, considering the input quality, cannot be very good in the first place) cannot replace the professional solutions.

Affordable devices have a substantial approximation of the actual values – and although the EEG principles apply even on this approximation, the data loss is so severe that the solutions cannot be recommended for any practical uses apart from the entertainment industry.

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