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IZVIRNI ZNANSTVENI ČLANEK

Psychophysiological evaluation of a simple EEG device

Gregor Geršak[1], Rok Tavčar[2]

Univerza v Ljubljani, Fakulteta za elektrotehniko, Tržaška 25, 1000 Ljubljana, Slovenija
[1]E-pošta: gregor.gersak@fe.uni-lj.si
[2]E-pošta: roktav@gmail.com

Abstract. Over the last decade the interest of researchers in the psychological effects on the human physiology has been increasing. Along with scientific measuring instruments, a number of entertainment and gaming devices using psychophysiological parameters has also emerged on the market. In this paper, a psychophysiological evaluation of one of these devices is presented. A gaming device working on the principle of a simple EEG measurement is tested using a simple psychophysiological test and measurement of the skin conductance and temperature. The results indicate that the device gaming function uses a complex input parameter composed of an EEG signal and skin impedance of the player measured by its electrodes.

Ključne besede: EEG, psychophysiology, Mindflex, Biopac, evaluation

Psihofiziološko ovrednotenje preproste EEG-naprave

V zadnjem desetletju se je zanimanje raziskovalcev psiholoških učinkov na človekovo fiziologijo zelo povečalo. Poleg znanstvenih merilnih instrumentov obstaja tudi množica naprav zabavne elektronike, ki tudi uporabljajo psihofiziološke parametre. Ena od naprav, ki uporabljajo preprost EEG, je bila testirana s preprostim psihofiziološkim testom. Test je vključeval merjenje prevodnost in temperature kože. Rezultati kažejo, da testirana naprava uporablja kompleksen vhodni parameter, sestavljen iz EEG in prevodnosti kože igralca.

1 INTRODUCTION

The use of objective methods measuring changes in the human physiology is becoming increasingly important. Multiparameter, portable, battery-powered body-worn devices capable of acquiring the level of the human physical activity are more and more common. Apart from monitoring the human physical activity, changes in the human physiology induced by psychological effects, i.e. psychophysiology, are increasingly researched.

Response studies of the human autonomous nervous system enable the human emotional state, mental load and other psychological characteristics to be evaluated. Physiological parameters such as heart rate, blood pressure, skin temperature, electrodermal activity, and microcirculation, are strongly correlated with the activity of the human autonomous nervous system which depends on the human psychophysiological state. The psychophysiological measurements measure the human' physiological parameters which vary due to their psychological state. By exploring the various mechanical, physical and biochemical phenomena in organisms, the physiological measurements determine how different external human physical, chemical and biological parameters affect the human organism. Usually they are taken for purpose of diagnostics, treatment, or therapy [1].

The psychophysiological instrumentation can be defined as a biomedical instrumentation used for measuring the human physiological responses due to changes in the human psychological state of the participant.

The physiological signals like the skin conductance (SC), heart rate (HR), skin temperature (SKT) and brain activity signals, such as electroencephalogram (EEG) are often used when assessing the human psychological state. The former are autonomous nervous-system-dependent, while EEG, the signal of voltage fluctuations in the brain, is also central nervous-system-dependent, i.e. it depends on the human psychological state, emotions, experiences etc.

The MindFlex (by Mattel Inc.) device is a consumer gaming toy based on the EEG measurements. It consists of two parts, a headband and main console. With her/his brain electrical activity the player controls a foam ball levitating on top of an air stream generated by a fan integrated in the main console. The device measures a simple EEG activity from which it calculates certain brain-wave patterns and uses them as controlling signals for the air fan. The task of the player is to lift the foam ball by mentally focusing and increasing her/his attention and to lower it by mentally relaxing. The main objective of the game is to guide the foam ball safely through different obstacles positioned on the main console.

The main part of the MindFlex device is an EEG acquisition chip (by NeuroSky) fitted into the headband

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with three dry electrodes (a reference and two baseline electrodes). The EEG chip provides an AD conversion and amplification of the EEG channels in order to acquire the brain-wave patterns. A wireless transmission enables the air fan to be controlled. The device is battery-powered. The relative low cost, portability and excellent straightforwardness of the EEG feedback loop representation open numerous new opportunities for simple academic presentations of the neuroscientific easy examples of exploring the brain waves and conducting various types of simple neuroscientific and psychophysiological experiments.

Although a toy, the Mindflex device has been used in a couple of scientific publications, mainly as a stimulation tool and as part of a psychological task of the experimental protocol [4-7]. On the other hand, there have been some studies showing that the Mindflex device can function also when there is no EEG signal (e.g. when the headband electrodes are attached to a wet cloth) [8].

In this paper we present results of our researching the changes in the psychophysiological parameters during playing the Mindflex game and show a link between the EEG brain-activity signals and controlling the fan and levitation of the foam ball.

2 METHODS

Our measurements were performed on a volunteering healthy male person. He was explained the measuring protocol and requirements for reliable and accurate measurements, e.g. the importance of silence, relaxation, comfortable and correct posture for avoiding moving artefacts etc.

The person used the MindFlex device with an EEG headband attached to his forehead and earlobes. Additionally, the physiological parameters of his electrodermal activity and SKT were also monitored by using a Biopac MP150 acquisition system.

2.1 Physiological measurements

SC and SKT were measured by the Biopac MP150 (by Biopac Inc. USA) acquisition system with the Biopac GSR100C and Biopac SKT100C modules, respectively. SC is one of the most frequently used physiological parameters in psychology, particularly to evaluate the state of the human autonomous nervous system, emotional arousal, stress evaluation, different medical states, etc. [2, 3]. Silver-silver chloride (Ag/AgCl) skin-conductance electrodes were placed on the person's distal phalanges of the first and second finger of the right hand (Figure 1). The electrolyte gel was used to enhance the electrical contact skin-electrodes. A five-minute wait time was allowed for an optimal electrical contact. The GSR100C amplifier was set to a 5 μS/V sensitivity and 10 Hz analog low-pass filter. A fast thermistor to measure SKT was positioned on the person's little finger of the right hand (Figure 1). The SKT amplifier was set to a 2 °C/V sensitivity and 10 Hz low-pass filter. The data was sampled at a frequency of 1 kHz. The Signal was processed by using the AcqKnowledge 4.1 software (by Biopac, USA). SC was estimated by monitoring the SC level (SCL). The SC and SKT signals that were digitally smoothed (five samples) were not conditioned.

2.2 Mindflex air fan and EEG signal

The driving voltage of the Mindflex air fan was connected to the Biopac data-acquisition system and was recorded with a sampling frequency of 1 kHz. In this way the foam-ball height was estimated and with it also the functionality and response of the main Mindflex unit by using the EEG signals.

The EEG signal was acquired in the form of a Neurosky chip output matrix using a serial communication from the EEG chip to the main console. A virtual instrument was designed for parsing the data into eight EEG waveforms, Attention and Meditation parameters and error signal which controls the recalibration intervals of the headband and connection issues. Connecting the acquisition system via an RS-232 serial port of a portable, battery-powered computer to the Tx and Rx pins of the headband enabled the EEG signal to be recorded. Such measuring set-up resulted in an additional noise and signal offsets which were resolved by using optically isolated connections.

2.3 Evaluation of the device performance

The person was seated in front of the MindFlex device with an EEG headband attached firmly to his forehead and earlobes (Figure 1). The Mindflex device performance was evaluated by using the measuring protocol consisting of the relaxation, lifting and static no-EEG phases.

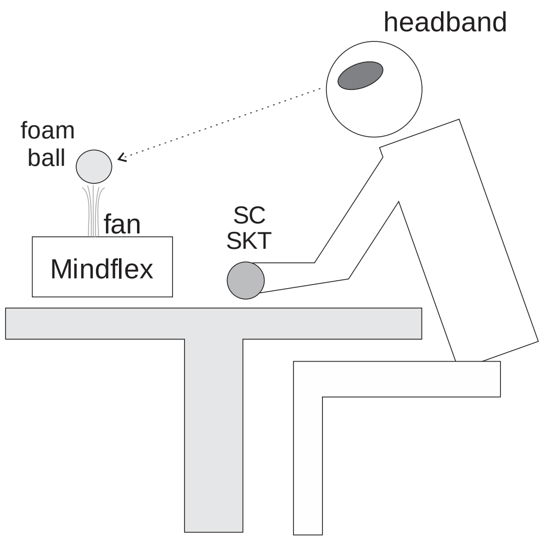


Figure 1. Schematics of the used measuring set-up. The EEG signals from the headband, SC and SKT were acquired. The foam ball was levitating on a stream of air produced by a fan integrated in the Mindflex console.

The first part of the measuring protocol was a phase during which the person was instructed to mentally relax. The relaxation phase was enabled by watching a long, soothing, meditation video (nature, birds singing) using headphones. The headphones were used to limit the fan noise, thus minimizing the psychological effect of the fan sound. During this phase the psychophysiological parameters were recorded and the baseline levels estimated.

In the next phase the person was instructed to lift the foam ball a couple of times using his mind only and possibly with a constant time between the lifts to enable monitoring the isolated changes in the psychophysiological parameters. The person was instructed to press a trigger to indicate the moment he voluntarily started to lift the foam ball or the moment he voluntarily started to lower the ball.

In the last phase, the headband electrodes were short-circuited, i.e. connected to an under 1 Ω resistor. Thus, the functionally of the device was checked when there was no physiological EEG signal. The effects of the extraneous electromagnetic fields were minimised by physically moving the set-up away from the sources of the magnetic field and by electrical shielding.

As the device used the EEG signal Attention to control the fan, the correlation function between the fan power and Attention signal was estimated.

3 Results

The signals acquired during the experiment used for the psychophysiological parameters of SC and SKT, EEG-based signals (eight brain-wave signals and Attention and Relaxation) and fan-power signal.

During the relaxation phase, the SC level was gradually decreasing indicating an increasing relaxation (Figure 2). Some SC responses and SCL changes were visible. Based on the person's self-reporting, this did not correspond significantly to the fan power. At an induced psychological stress, i.e. slap on the person's lower arm (marked with a vertical line in Figure 3), both SC and SKT signals changed as expected. Due to the increased activity of the sweat glands SCL increased and simultaneously, due to vasoconstriction of the veins resulting in a lower blood flux SKT decreased.

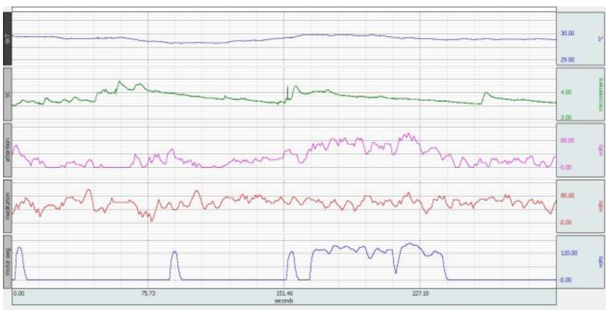
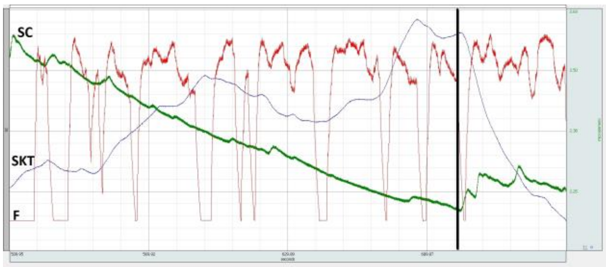


Figure 2. General signal recording (from top to bottom): psychophysiology (SC and SKT), EEG signal (Attention and Relaxation) versus the fan activity.

As seen from our results, though the person was in a relaxed state in which in theory his attention and relaxation levels should be constant, the fan control was changing dynamically (the bottom line in Figure 2).

Figure 3. Three-minute section of recording the fan power (F), SKT and SC during the relaxation phase of the protocol. The vertical line marks a slap on the person's lower-arm inducing changes in ST and SC.



In the second phase the person tried to lift the ball only with his electrical brain-activity EEG signal. In Figure 4, SC, SKT and Attention are shown. The person was instructed to mark the moment when he started to mentally move the foam ball (the marks are shown as the pulses in Figure 4). Generally, these marks correspond to an actual change of ball levitation direction.

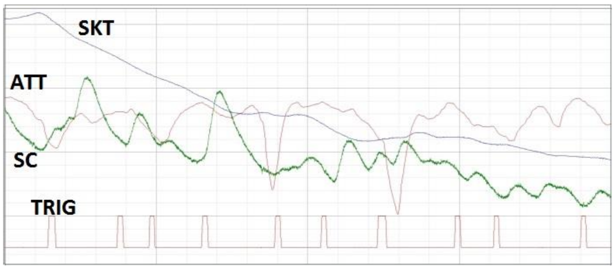


Figure 4. Three-minute measurements of the EEG Attention signal ATT, SKT and SC as compared to the fan power (TRIG). The pulses (below) indicate a change in the direction of levitation of the foam ball, e.g. one pulse indicates the perceived start of lifting the ball, the next of lowering the ball.

In the last phase the situation with no actual physiological EEG signal was researched. The short-circuited EEG electrodes resulted in clearly visible changes in the foam ball height and fan power. Thus we proved that the lack of EEG component did not stop the toy device to lift the foam ball from the initial static state and to dynamically change the ball height.

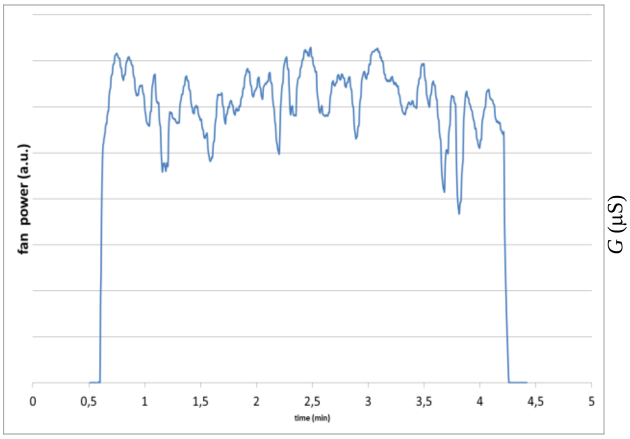


Figure 5. Fan power signal corresponding to the foam ball height when the Mindflex electrodes were short-circuited (no EEG signal present).

In Figures 5 and 6, a certain degree of correlation between the fan power (foam-ball height) and EEG attention signal monitored by the Mindflex device is shown. The conclusion drawn from our results is that Attention is the controlling signal for the fan lifting the foam ball.

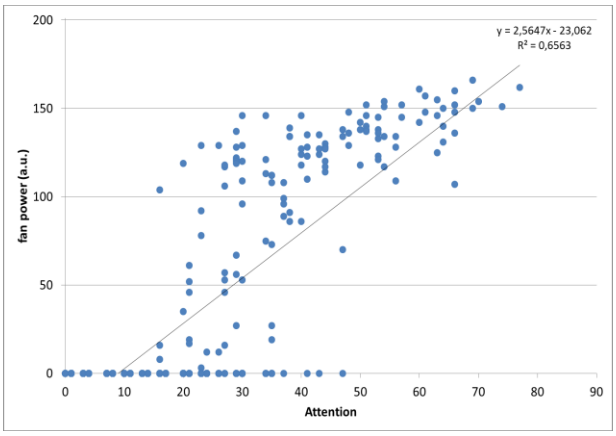


Figure 6. Correlation between the fan power and Attention signal form the EEG chip in Mindflex headband.

Figure 7 shows the correlation between the fan power and EEG attention signal.

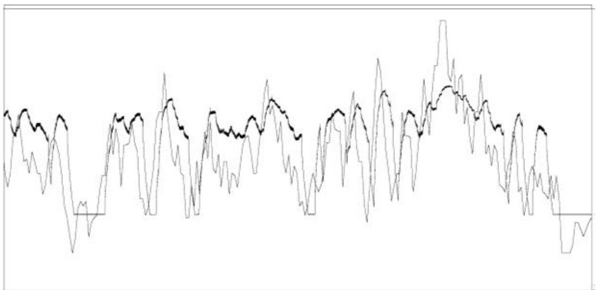


Figure 7. Three-minute measurement of the EEG attention signal and fan power.

4 CONCLUSION

A simple EEG device, the Mindflex toy is evaluated by means of psychophysiological measurements. Despite being a pilot experiment with only one person observed, some new knowledge is gained. The results of our measurements are similar to those given in publications with the Mindflex devise functioning with no EEG signal [8]. The Mindflex EEG controlling signal is speculated to be a complex function of EEG attention signal and electrode impedance. Such control results in what seems to be a stochastic ball lifting. It should however, be noted that the physiological EEG signal is indeed needed for a voluntary foam-ball lifting. In the opposite case the foam ball would not move in a controlled manner.

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Gregor Geršak je doktoriral leta 2003 na Fakulteti za elektrotehniko Univerze v Ljubljani. Njegovo raziskovalno področje obsega teorijo merjenja, precizijsko merjenje gostote magnetnega pretoka, tlaka in termometrije. V zadnjih letih se ukvarja z meroslovjem biomedicinske instrumentacije s poudarkom na napravah za neinvazivno merjenje krvnega tlaka in s psihofiziološkimi merjenji.

Rok Tavčar je diplomiral leta 2014 na Fakulteti za elektrotehniko Univerze v Ljubljani. Trenutno je študent magistrskega študijskega programa Avtomatika in informatika. V zadnjih letih se ukvarja tudi s programiranjem mikrokrmilnikov.