NEUROBOT: A psycho-edutainment tool to perform neurofeedback training in children with ADHD

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Abstract. Neurofeedback is a type of biofeedback useful to help people learn, through training, to modify amplitude, frequency, and coherence of the electrophysiological aspects of his brain.

In this paper, we present a neurofeedback-based training for children affected by attention deficit and hyperactivity disorder (ADHD). The aim of the project is to use a more engaging training mode, transforming a traditional neurofeedback training session into a competition that consists in commanding a Lego® robot using brain waves.

Using neurofeedback, the person has a clear visualization and perception in real-time of his own electroencephalographic activity because the brain activity is displayed on a computer monitor. With this training, the brain is educated to produce brain waves in specific amplitudes and in specific positions. The person, therefore, becomes capable of re-educating himself, until he reaches the desired pattern of brain activity. The proposed system consists in a computer software, a Lego Mindstorm® kit and an electroencephalogram cap. The aim of the game is to focus the player's attention and concentration on a colored disk placed on the robot: if the player focuses enough attention on the colored disk, the robot's speed will increase, so the robot could win the race against other player's robots.

Keywords: ADHD, neurofeedback, robot.

1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurobehavioral disorders. It occurs, in early childhood, mainly with two classes of symptoms: an evident level of inattention and a series of behaviors that denote hyperactivity and impulsivity. This disorder is considered a potentially chronic condition, which presents symptoms that affect various functional aspects of everyday life. The symptoms related to inattention are found above all in children who, compared to their peers, have severe difficulties in focusing attention on the same task for a sufficiently long period of time or during games. Usually, children with ADHD are unable to follow the instructions given during a game or a task, they are disorganized and careless in their school activities, they have difficulty maintaining concentration, they are easily distracted by their mates and rarely manage to complete a task.

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Based on the criteria of the DSM-5 diagnostic manual [1], ADHD manifestations can be distinguished in: ADHD with predominant inattention, ADHD with pre-dominant hyperactivity/impulsivity and combined ADHD. Statistically, it is believed that attention deficit/hyperactivity disorder affects 5% of the childhood population and 2.5% of adulthood.

Pharmacological and psycho-educational treatments are preferred to reduce the risk factors of the ADHD but, in addition, some studies have shown improvements in attention performances in children who follow psychoeducational treatments like Neurofeedback training. Neurofeedback is a tool that allows to detect the cerebral electrical activity and present it visually and in real-time through a computer or tablet screen, based on the fact that each cortical activity corresponds to a different type of brain wave. Using the feedback displayed on a computer monitor, the individual can learn a "brain behavior", and can try to modify his electro encephalic activity by searching for the desired cognitive state. The person who undergoes the treatment will thus be able to observe and subsequently learn to "manage" the feedback relating to cognitive activity and voluntarily reach the desired states. It is known that electro-encephalic activation is divided into four categories of waves that change due to their different frequency. The theta waves (4 - 7 Hz) correspond to the state of pre and post-sleep, (i.e. a state of deep relaxation); delta waves (1 - 3 Hz) are connected to deep sleep; the alpha waves (8 -13 Hz) are more active during the relaxed waking state, while the processes of focusing and cognitive processing (concentration on a task and its execution) are connected to an increase in the activity of beta waves (14 - 30 Hz) in the frontal brain areas [2]. These frontal areas, together with the central areas, are the areas indicated in some studies that have a different type of electrical activation in individuals with ADHD, compared to individuals without ADHD diagnosis [3].

In the scientific literature, some studies highlight the greater presence of theta slow waves in subjects with ADHD and a lack of beta waves. These observations on the lack of beta waves would explain the lower ability of children with ADHD to remain focused on a given task [4], while the greater presence of theta waves could explain the inattention and decentralized thinking of children with ADHD [5].

Based on these studies, Neurofeedback training tries to modify brain activity in order to improve the cognitive and behavioral performance of the individual [6] by acting on brain waves.

A recent, study carried out in 2014 on 144 patients of school age and diagnosed with ADHD, showed performance improvements following Neurofeedback training. The data was evaluated through the administration of a battery of tests that revealed the variations in performance inherent to the ADHD symptomatology comparing the symptoms before and after treatment [7].

The scientific literature supports the use of neurofeedback training for attention disorders, however, the scarce diffusion of applications and software for school-age children did not allow the spread of these training. Without elements of gameplay [8], it is really difficult to capture the interest of a child at school age, especially when these training sessions require high numbers of learning sessions to give a good result [9].

About these considerations, it was decided to carry out a neurofeedback training, useful to guarantee a greater involvement by the user/child, integrating gamification

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[10] elements in order to stimulate social involvement through a challenge between peers and an extremely attractive element for children, such as a robot [11].

2 Intervention

A software application was created, in order to gather information on the attention value coming from an EEG device worn by the user and, based on this parameter, to activate or deactivate the acceleration of a robot. The aim of the game consists in a race among the robots, where the winning robot is the one who has traveled more in less time and therefore will be the one "driven" by the user who has been most focused. The aim is to make the young player aware of his state of brain activation, not through a graphic or a projection on a computer, but through the movement of an object, more motivating and engaging [12, 13].

2.1 Materials And Methods

The application consists in a BrainWave Mobile Kit headset kit [14], a Lego® [15] robot built in the form of a rover, a notebook with dedicated software and an arena with a length of 230cm.

The BrainWave Mobile 2 Kit, it is an EEG headset distributed by NeuroSky® that safely record the electrical activity of the brain (alpha waves, beta waves, etc.) and send it via Bluetooth Low Energy (BLE) to a Windows, iOS or Android device. This headset can determine different emotional states, using only a sensor on the forehead. The following outputs are recorded: Attention, Meditation, Eyeblinks, Brainwave Bands (e.g. delta, theta, alpha, beta, etc.) and Raw Output.

To determine mental states the headset provides an SDK (software development kit) called eSense™ [16] and powered by a proprietary algorithm that measures activation on a scale of 1 to 100 [17].

For this study, a software application, created ad-hoc with Unity and installed on a notebook was used. This software, leveraging the attention parameter provided by the e-Sense algorithm, can let a Lego® robot, connected via Bluetooth, accelerate with a speed equal to half the motor's maximum power.

"Infinite Runner" is a Unity based game, which can be played with the help of the NeuroSky MindWave device. The game character runs continuously and there as many obstacles in his path. Each obstacle decreases the power, and when the power goes to zero the character is dead. The user can avoid the obstacles by jumping. The user can also slows down if the focus value goes up and run fast if the focus goes up. Moreover, the character stops moving if the attention level decreases beyond a certain threshold. Raw brainwaves are used to calculate scaled attention and meditation values of the player's mind, which are then passed to the game. The software records the attention level every 1 second and the session logs are stored in an Excel spreadsheet.

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2.2 Experimental design, description of the training session and duration

The hypothesis of this pilot study is to verify whether the neurofeedback training sessions involving interaction with real-world objects can give the user awareness of his brain state more effectively than traditional feedback training involving only a computer exercise and a visualization of the brain activation values.

The experimental design used to verify our hypothesis is of type ABAB. As known, ABAB (OXOX) examines the effects of an intervention alternating the basic condition (phase A or O), in which no intervention is in progress, with the intervention condition (phase B or X), in which it is implemented the treatment.

The experimental conditions are as follows:

- The user is placed in front of the screen of a notebook placed on a desk, on his head a position operator a MindWave Mobile kit 2 headset
- The user is asked to play a game of attention specially modified for the purpose of research, whose source code is provided by the manufacturer NeuroSky inc. and called "Infinite Runner".

3 Results

The data of presented pilot study was collected in 10 training sessions, lasting about 30 minutes, one week apart from the other. The test subject was a 10-year-old child, D., diagnosed with ADHD. Before and during the trial the child did not follow any rehabilitation program and did not take any medication.

The data were summarized in a table consisting of means per session. The two variables were compared with a One-Way ANOVA Test using the PSPP software from the GNU Project.

Table 1. Means per session.

Training	A	B
1	51,24	51,684
2	51,739	52,075
3	50,913	52,117
4	50,412	54,844
5	51,16	54,323

The analysis of the data showed $p < .05$, highlighting the significance of the data between the two variables A and B.

Table 2. One-Way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
MEANS	Between groups	9,18	1	9,18	7,76	0,024

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Within groups	9,46	8	1,18
Total	18,63	9	

The pilot study presents many critical issues; in particular, the research should be extended both in participants and in training sessions. The software should propose an interaction similar to the hardware solution, or vice versa, in order to reproduce a similar experience, but considering the results obtained with the pilot study, we believe that a more solid experimentation will be possible in the future.

4 Conclusions

The data collected indicate a predisposition of the subject involved in the study with respect to concrete stimuli in the environment. The second condition reported better results than the first.

Modern technological opportunities allow us to create engaging interactions even for children who have difficulty focusing attention. Using these innovations to channel and not waste the attention of young patients remains one of the most interesting challenges the future holds for us.

References

1. American Psychiatric Association: Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub (2013).
2. Deilami, M., Jahandideh, A., Kazemnejad, Y., Fakour, Y., Alipoor, S., Rabiee, F., Pournesaie, G.S., Heidari, R.N., Mosavi, S.A.: The effect of neurofeedback therapy on reducing symptoms associated with attention deficit hyperactivity disorder: a case series study. Basic Clin. Neurosci. 7, 167 (2016).
3. Loo, S.K., Barkley, R.A.: Clinical utility of EEG in attention deficit hyperactivity disorder. Appl. Neuropsychol. 12, 64–76 (2005).
4. Wangler, S., Gevensleben, H., Albrecht, B., Studer, P., Rothenberger, A., Moll, G.H., Heinrich, H.: Neurofeedback in children with ADHD: specific event-related potential findings of a randomized controlled trial. Clin. Neurophysiol. 122, 942–950 (2011).
5. Swartwood, J.N., Swartwood, M.O., Lubar, J.F., Timmermann, D.L.: EEG differences in ADHD-combined type during baseline and cognitive tasks. Pediatr. Neurol. 28, 199–204 (2003).
6. Becerra, J., Fernandez, T., Harmony, T., Caballero, M.I., Garcia, F., Fernandez-Bouzas, A., Santiago-Rodríguez, E., Prado-Alcalá, R.A.: Follow-up study of learning-disabled children treated with neurofeedback or placebo. Clin. EEG Neurosci. 37, 198–203 (2006).
7. Holtmann, M., Sonuga-Barke, E., Cortese, S., Brandeis, D.: Neurofeedback for ADHD: a review of current evidence. Child Adolesc. Psychiatr. Clin. 23, 789–806 (2014).

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8. Ponticorvo, M., Di Fuccio, R., Ferrara, F., Rega, A., Miglino, O.: Multisensory Educational Materials: Five Senses to Learn. In: International Conference in Methodologies and intelligent Systems for Techhnology Enhanced Learning. pp. 45–52. Springer (2018).
9. Cerrato, A., Siano, G., De Marco, A.: Augmented Reality: from education and training applications to assessment procedures. Qwerty-Open Interdiscip. J. Technol. Cult. Educ. 13, (2018).
10. Cerrato, A., Ferrara, F., Ponticorvo, M., Sica, L.S., Di Ferdinando, A., Miglino, O.: DILIGO assessment tool: A smart and gamified approach for preschool children assessment. In: International Conference on Smart Education and Smart E-Learning. pp. 235–244. Springer (2017).
11. Miglino, O., Di Ferdinando, A., Di Fuccio, R., Rega, A., Ricci, C., Schembri, M., Ricci, C.: Bridging Digital and Physical Educational Games Using RFID/NFC Technologies. J. E-Learinig Knowl. Soc. 3, 87–104 (2014).
12. Rega, A., Mennitto, A., Vita, S., Iovino, L.: New Technologies And Autism: Can Augmented Reality (Ar) Increase The Motivation In Children With Autism? In: INTED2018 Proceedings. pp. 4904–4910 (2018). https://doi.org/10.21125/inted.2018.0959.
13. Rega, A., Mennitto, A.: Augmented Reality As An Educational And Rehabilitation Support For Developmental Dyslexia. In: ICERI2017 Proceedings. pp. 6969–6972 (2017).
14. NeuroSky Inc.: EEG - ECG - Biosensors, http://neurosky.com/.
15. The LEGO Group: Mindstorms LEGO.com, https://www.lego.com/mindstorms.
16. NeuroSky Inc.: NeuroSky's eSense ™ Meters and Detection of Mental State Introduction and Background. Methods. (2009).
17. Ponticorvo, M., Rega, A., Di Ferdinando, A., Marocco, D., Miglino, O.: Approaches to embed bio-inspired computational algorithms in educational and serious games. CEUR Workshop Proceedings, 2099, 8-14, (2018).

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