Mobile Devices and Systems in ADHD Treatment

Renato Montaleão Brum Alves, Mônica Ferreira da Silva, Eber Assis Schmitz
and Antonio Juarez Alencar
Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil

Keywords: ADHD, Mobile, Neurofeedback, Serious Games, Treatment.

Abstract: Attention Deficit Hyperactivity Disorder (ADHD) is a neurobiological condition that appears during an individual's childhood and may follow her/him for life. Even though it is not a new disorder, ADHD treatment is limited to the use of drugs and behavioral therapy, even for children. The objective of this research was to investigate the technological possibilities of mobile devices and web-based information systems, as well as other computer technologies, to support the ADHD treatment phase. Results show the potential of these approaches as alternatives for long-term treatment, as well as the difficulties and limitations that persist today. Besides, the research also highlighted that the use of computer technology could provide persistent long-term results.

1 INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurobiological conditions that affects children. Faraone, Biederman, & Mick (2006) found out that, in 65% of the cases, ADHD persists into adolescence and adulthood.

The current treatment for this neurodevelopmental disorder includes a combination of medication and psychotherapy. Despite the relative success of pharmaceutical therapies in ADHD, there are essential reasons to identify alternative non-invasive methods. First, the list of side effects includes headaches, mood swings, nausea and dizziness. Besides, prescribing drugs to young children involves risks not yet thoroughly and surely studied. Lastly, medicine is not equally effective for ADHD subgroups.

The treatment phase of ADHD offers a vast field for research, and computer technologies play a promising role in this regard. Systems have been used for such purpose since 1985, through the software CAPTAIN (Gomez & Carro, 2014). Since then, technology has evolved, especially in the mobile segment.

This work aimed to investigate the technological advances of web-based information systems, as well as other computer technologies, to support the ADHD treatment phase. Through this research work, it was possible to verify which are the leading computational technologies today. The results show the potential of these approaches as alternatives for long-term treatment for patients in childhood or adulthood, indicating that the use of some technologies produces lasting effects, even when application is interrupted. Also, the difficulties and limitations emerged from the analyses carried out.

2 USE OF MOBILE AND WEB COMPUTER TECHNOLOGY FOR ADHD TREATMENT

In some locations, access to psychotherapeutic treatment is practically impossible due to distance or mobility issues. For this reason, mobile technology associated with web resources may be the only form of treatment for some patients. IT Systems have been used to treat ADHD since 1985 (Gomez & Carro, 2014). In our research, we used literature systematic review techniques to identify several published papers in recent years, dealing with the use of technology as a means of non-invasive treatment. Among the most used technologies, we can highlight Neurofeedback, followed by Serious Games, and the combined use of both approaches. Also, approximately 15% of scientific research reported the use of web remote assistance technology by video conferencing or data monitoring capabilities.

Alves, R., Ferreira da Silva, M., Schmitz, E. and Alencar, A.
Mobile Devices and Systems in ADHD Treatment.
DOI: 10.5220/0010148201410146
In *Proceedings of the 16th International Conference on Web Information Systems and Technologies (WEBIST 2020)*, pages 141-146
ISBN: 978-989-758-478-7

2.1 Neurofeedback

Neurofeedback is a neural self-regulation technique that allows individuals to modulate their brain frequencies using visual, auditory reinforcements, or both, usually displayed on the screen of a computing device. The training based on such technique, designed to change an individual's brain activity, has been in use for nearly four decades and accounting for one of the first applications of brain-computer interfaces. Most studies are based on electroencephalogram (EEG) recordings and apply neurofeedback in clinical contexts, exploring its potential as a treatment for psychopathological syndromes.

Cowley et al., (2016) carried out a controlled clinical trial of neurofeedback therapeutic intervention in ADHD for adults. The EEG device used was *Enobio* from the company Neuroelectrics SL. The software developed was based on the OpenViBE[1] signal acquisition framework with Qt frontend, and it is available as an open source. As a result, the technique improved self-reported ADHD symptoms.

Another study using the same technique analyzed the differences between inattentive and hyperactive subtypes using the *BrainMaster* software. The results indicated that the predominantly inattentive group showed relevant differences on the control scale and the attention scale. The predominantly hyperactive group showed improvement in the control scale. The control group showed no significant difference in either scale. Findings suggest that neurofeedback training using the theta/beta protocol was more effective in the predominantly inattentive subset of individuals (Duarte Hernández, González Marqués, & M. Alvarado, 2017).

A variation of such an approach by Azman, Mansor & Lee (2018) evaluated the use of a physical race car game to treat children. Wireless data transmission to transfer brain signal data was used to move and stop the car. A program installed on the microcontroller was used to control the car's motion. NeuroSky MindWave Mobile EEG was connected to the Arduino UNO and Toys"R"Us Fastlane Slot Car via Bluetooth. As the NeuroSky MindWave receives the user's brain signal, the car is activated if the user concentrates and gives it full attention. Arduino UNO was used as a controller to detect the level of attention embedded in the brain signal and activate the Toys"R"Us Fastlane Slot Car.

In another variation, experimented by Shin *et al.* (2016), a tablet was used to verify whether the neurofeedback technique could improve brain executive functions. Forty children participated in the experiment using the equipment connected to a mobile brainwave monitor. Several neuropsychological tests were carried out after training with the devices, and the conclusion was that there was an improvement in the cognitive function. The good results remained during the follow-up period.

Two other surveys also verified the permanence of the training effect months after it ended. One of them performed experiments with adolescents using real-time functional magnetic resonance imaging neurofeedback (rtfMRI-NF). Results showed significant increases in linear activation in the target regions, and a reduction in ADHD symptoms during the 11 months of follow-up (Alegria et al., 2017).

The second survey analyzed aimed at assessing sustained improvements after six months of applying neurofeedback to children. One hundred and four children received cognitive training, neurofeedback treatment, or were placed in the control status. The neurofeedback system used was *Play Attention*[2], from the company Unique Logic and Technology. Brainwaves were measured by an EEG sensor built in a bicycle helmet, centrally located at the top of the skull, and two others bilaterally located EEG sensors. Individuals who used neurofeedback had more significant improvements in ADHD symptoms as compared to those in the control group or undergoing cognitive treatment and maintained them during the 6-month follow-up period (Steiner *et al.*, 2014).

On the other hand, Bink *et al.* (2015) reported an experiment with negative results concerning the superior effectiveness of neurofeedback approach. The EEG signal was sent to the computer using Brainquiry PET and the training conducted with EEGer software. The combination of usual treatment with neurofeedback was not more effective than applying the standard therapy alone. However, the software interface does not seem to encourage its use and, without the aid of a serious game, engagement of individuals with attention-deficit may have been jeopardized.

Lastly, an unsuccessful use of neurofeedback software: a study investigated the effect of a system called *ACTIVATE*™ that targets a wide range of cognitive functions. Seventy children with ADHD participated in the experience. The intervention group used *ACTIVATE*™ for 8 weeks. Both groups were

[1]http://openvibe.inria.fr/

[2]http://www.playattention.com/

evaluated regarding cognitive functions, symptoms, behavioral and functional outcomes after 8, 12 and 24 weeks. The clinical trial found no significant effect on cognitive training (Bikic et al., 2018).

2.2 Serious Games

Attention-training games based on Brain-Computer Interface (BCI) have proved positive in the treatment of children with ADHD, specifically with inattentive symptoms. Five research papers analyzed used neurofeedback techniques combined with serious games. Rohani, Sorensen & Puthusserypady (2014), for example, introduced a system aimed at treating children with ADHD. To do so, a virtual classroom environment was developed using *Unity3D* game engine with SDK, *BLENDER 3D* modeling software, and Microsoft *Kinect*.

Other three studies also used the *Unity3D SDK* platform. Ochi et al. (2017) developed a serious game with neurofeedback for attention training in adults with ADHD. The *game* Armis was generated using the Unity platform. The results suggested that this type of therapy may be effective as an alternative treatment since the high-risk group achieved significant improvement.

Chen et al. (2018) used the same development platform and the same EGG mobile monitor, *NeuroSky MindWave*, to detect brainwaves and then apply them to the game. Finally, using the Conners' Continuous Performance Test / Conners Kiddie Continuous Performance Test (CPT / KCPT), a significant improvement was observed in the attention and focus of children who participated in the study.

Alchalcabi, Eddin & Shirmohammadi (2017) designed a virtual reality serious game, also using the Unity SDK, with the EGG device called *EMOTIV EPOC+*. The goal was to improve the focused capacity in individuals with ADHD and ADD. Preliminary experiments with healthy individuals showed an average improvement of 10% in engagement and 8% in focus for persons who used the EEG-controlled game, compared to those who used the same game but controlling it by the keyboard.

The third study examined the topological changes of the brain functional networks induced by the 8-week BCI-based attention intervention. The attention training game consisted of a head arc with EEG sensors that sent brainwave readings to the computer. The tested group showed a reduction in inattention symptoms followed by differential brain network reorganization after the training (Qian et al., 2018).

On the other hand, we have serious games-focused studies used without neurofeedback. Dovis et al. (2015) trained several executive roles of children with ADHD through a software called *Braingame Brian*. It is a computer-based executive function training, turned into a serious game. The results suggested the beneficial effects of treatment perceived using technology.

In another study, authors carried out a case study with a 10-year-old patient. The child was treated using medication along with a new video game-based cognitive training method called the TCT method. The cognitive areas in which improvement was observed were the spatial working memory and fine motor skills. The technique improves cognitive skills such as attention, working memory, processing speed, calculating ability, and reasoning, as well as visual-motor coordination. As a result, the researchers highlighted that regular computer-based cognitive training can improve some of the cognitive ADHD symptoms and still be useful to treat video game addiction. (Ruiz-Manrique, Tajima-Pozo & Montañes-Rada, 2015).

In 2015, a group of researchers developed a serious game called *Plan-It Commander*, designed to promote behavioral learning and strategy use in everyday life situations known to be problematic for children with ADHD. The game content and approach are based on the psychological principles of the Self-Regulation Model, the Social Cognitive Theory, and the Learning Theory. A survey was carried out with 42 children with ADHD, in order to gather user feedback on a prototype of the game. Children guardians also participated and reported a significant improvement of children in time management, planning and frustration tolerance issues (Bul et al., 2015).

In 2018, the same researchers tried to identify which subgroups of children with ADHD benefited most from treatment using a serious game. As a conclusion, the study found two groups that benefited most from the intervention: girls in general and boys with lower scores on hyperactivity and higher scores with Conduct Disorder symptoms. (Bul et al., 2018).

2.3 Remote Web Treatment

There are still many barriers to access personalized therapeutic content, either due to the distance between patients and large urban centers, or even because of displacement difficulties. That is the reason why the use of remote technology for treatment has been arousing interest and may become a promising manner to offer behavioral interventions to parents and children with ADHD.

Sibley, Comer & Gonzalez (2017) investigated the therapy for parents and children in the videoconferencing format. A Cisco platform, called *Webex*[3], was used in the study. The families reported a high level of satisfaction with the experience. Therapists observed improvement for 50% of families. Teachers and parents observed reductions in ADHD symptoms, in the organization, time management, and planning issues.

In another study, videoconferencing was evaluated to provide behavioral interventions to the families of individuals with ADHD. The product used was the *Catalyst Common View*. Parents reported results comparable to conventional assistance (Tse, McCarty, Stoep, & Myers, 2015).

Simons et al. (2016) tried to explore the opinions and behavior of patients, parents and health professionals as regards the use of a remote monitoring system. A prototype was developed by the company QbTech and consisted of automated messages via SMS with an invitation to fill in Web forms on routine outcome measures, to monitor symptoms and side effects of medication prescribed.

2.4 Other Mobile and Web Computer Technologies

Using a touch screen desk, Gomez & Carro (2014) introduced the *AdaptADHD*, an app to support adaptive training and assessment for children and adolescents with ADHD during their therapies. The application aims to assist patients in improving their skills regarding concentration and impulse control. Besides, it supports the work of therapists in enabling patient monitoring.

Another software analyzed in the survey was the *Drive Smart*[4]. The authors believe that the risk of young drivers with ADHD is increased by correlation with the impaired ability to perceive risk. The study carried out aimed to verify the changes in the ability to sense danger in young drivers with ADHD, who received training through *Drive Smart*. The risk perception skills of respondents improved significantly after the training, and with some gain maintenance, found within 6 weeks of follow-up, after using the software. (Bruce et al., 2017).

iPads were also analyzed in the context of ADHD treatment. Schuck et al. (2016) evaluated the usefulness of a web-based application called *iSelfControl*. The system was designed to support classroom behavior management. The *iSelfControl* required that each student performed a self-assessment at predefined periods. Simultaneously, the teacher evaluated each student on a separate iPad. The app collected assessment discrepancies between teachers and students, as well as significant variations throughout the day.

In the context of social networks and wearables, Schoenfelder et al. (2017) used a device called *Fitbit Flex*: a smart wristband that allows physical monitoring information. They also used a social network to create an engagement group with weekly goals. Such technologies were used due to their interactivity features, which are promising for adolescents, a public with a higher risk of abandoning treatments. The results indicated improvement in adolescents' inattentive symptoms, as reported by their parents.

In another web technology evaluation, authors sought to verify the effect of an educational site on parental perceptions and knowledge levels. A total of 172 parents, whose children had ADHD, were recruited. After taking a 30-item basic knowledge test, parents were directed to an educational site on ADHD. Then they were contacted again for the follow-up test. 85.5% of the respondents regarded the use as relevant and would use it again. As an overall result, authors found that parents showed more significant knowledge of ADHD after using the site (Ryan, Haroon, & Melvin, 2015).

3 CONCLUSIONS AND FUTURE WORK

Non-invasive treatments for ADHD are as urgent as feasible through the web and mobile technology that exist today, revealing increasingly promising results. The use of technology also allows continuous treatment to be offered even to those who reside far from urban centers. In this article, we highlighted the current trends, main findings and some limitations of using mobile and web technology in the treatment phase of ADHD.

As shown in literature, mobile EEG technology combined with serious games has been effective in the treatment of ADHD. Our next step will be to evaluate the adoption of a prototype that allows the use of a domestic neurofeedback device in conjunction with a gamification strategy and a web system, to enable remote treatment and the support by health professionals.

The objective is to verify which human or technological factors impact the adoption of these

[3]http://www.webex.com

[4]http://drivesmart.vic.gov.au

tools, and which facilitators can drive the use of technology. For this purpose, we will verify such aspects under the perspective of Technology Acceptance Model (TAM) (Davis, 1989).

Another expected contribution of the research is to verify if the solution applies equally to all subtypes of ADHD. Still, as a future work of this research group, there is the objective of evaluating the possibilities of using computer technologies to assist in the diagnosis stage of ADHD disorder.

REFERENCES

Alchalcabi, A. E., Eddin, A. N., & Shirmohammadi, S. (2017). More attention, less deficit: Wearable EEG-based serious game for focus improvement. *2017 IEEE 5th International Conference on Serious Games and Applications for Health, SeGAH 2017*. https://doi.org/10.1109/SeGAH.2017.7939288.

Alegria, A. A., Wulff, M., Brinson, H., Barker, G. J., Norman, L. J., Brandeis, D., … Rubia, K. (2017). Real-time fMRI neurofeedback in adolescents with attention deficit hyperactivity disorder. *Human Brain Mapping*, *38*(6), 3190–3209. https://doi.org/10.1002/hbm.23584.

Azman, N. H., Mansor, W., & Lee, K. Y. (2018). Neuro based racing car for cognitive training. *IEEE Student Conference on Research and Development: Inspiring Technology for Humanity, SCOReD 2017 - Proceedings*, *2018-Janua*, 473–476. https://doi.org/10.1109/SCORED.2017.8305437.

Bikic, A., Leckman, J. F., Christensen, T., Bilenberg, N., & Dalsgaard, S. (2018). Attention and executive functions computer training for attention-deficit/hyperactivity disorder (ADHD): results from a randomized, controlled trial. *European Child and Adolescent Psychiatry*, *27*(12), 1563–1574. https://doi.org/10.1007/s00787-018-1151-y

Bink, M., van Nieuwenhuizen, C., Popma, A., Bongers, I. L., & van Boxtel, G. J. M. (2015). Behavioral effects of neurofeedback in adolescents with ADHD: a randomized controlled trial. *European Child and Adolescent Psychiatry*, *24*(9), 1035–1048. https://doi.org/10.1007/s00787-014-0655-3.

Bruce, C. R., Unsworth, C. A., Dillon, M. P., Tay, R., Falkmer, T., Bird, P., & Carey, L. M. (2017). Hazard perception skills of young drivers with Attention Deficit Hyperactivity Disorder (ADHD) can be improved with computer based driver training: An exploratory randomised controlled trial. *Accident Analysis & Prevention*, *109*, 70–77. https://doi.org/https://doi.org/10.1016/j.aap.2017.10.002.

Bul, K. C. M., Doove, L. L., Franken, I. H. A., Van Der Oord, S., Kato, P. M., & Maras, A. (2018). A serious game for children with Attention Deficit Hyperactivity Disorder: Who benefits the most? *PLoS ONE*, *13*(3), 1–18. https://doi.org/10.1371/journal.pone.0193681.

Bul, K. C. M., Franken, I. H. A., Van der Oord, S., Kato, P. M., Danckaerts, M., Vreeke, L. J., … Maras, A. (2015). Development and User Satisfaction of "Plan-It Commander," a Serious Game for Children with ADHD. *Games for Health Journal*, *4*(6), 502–512. https://doi.org/10.1089/g4h.2015.0021.

Chen, C. L., Tang, Y. W., Zhang, N. Q., & Shin, J. (2018). Neurofeedback based attention training for children with ADHD. *Proceedings - 2017 IEEE 8th International Conference on Awareness Science and Technology, ICAST 2017*, *2018-Janua*(iCAST), 93–97. https://doi.org/10.1109/ICAwST.2017.8256530.

Cowley, B., Holmström, É., Juurmaa, K., Kovarskis, L., & Krause, C. M. (2016). Computer Enabled Neuroplasticity Treatment: A Clinical Trial of a Novel Design for Neurofeedback Therapy in Adult ADHD. *Frontiers in Human Neuroscience*, *10*(May), 1–13. https://doi.org/10.3389/fnhum.2016.00205.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319. https://doi.org/10.2307/249008.

Dovis, S., Van Der Oord, S., Wiers, R. W., & Prins, P. J. M. (2015). Improving executive functioning in children with ADHD: Training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial. *PLoS ONE*, *10*(4), 1–30. https://doi.org/10.1371/journal.pone.0121651.

Duarte Hernández, E., González Marqués, J., & M. Alvarado, J. (2017). Effect of the theta-beta neurofeedback protocol as a function of subtype in children diagnosed with attention deficit hyperactivity disorder. *Spanish Journal of Psychology*, *19*(2016), 1–10. https://doi.org/10.1017/sjp.2016.31.

Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychological Medicine*. https://doi.org/10.1017/S003329170500471X.

Gomez, L., & Carro, R. M. (2014). Adaptive training of children with attention deficit hyperactivity disorder through multi-touch surfaces. *Proceedings - IEEE 14th International Conference on Advanced Learning Technologies, ICALT 2014*, 561–563. https://doi.org/10.1109/ICALT.2014.164.

Ochi, Y., Laksanasopin, T., Kaewkamnerdpong, B., & Thanasuan, K. (2017). Neurofeedback game for attention training in adults. *BMEiCON 2017 - 10th Biomedical Engineering International Conference*, *2017-Janua*, 1–5. https://doi.org/10.1109/BMEiCON.2017.8229113.

Qian, X., Loo, B. R. Y., Castellanos, F. X., Liu, S., Koh, H. L., Poh, X. W. W., … Zhou, J. (2018). Brain-computer-interface-based intervention re-normalizes brain functional network topology in children with attention deficit/hyperactivity disorder. *Translational Psychiatry*, *8*(1). https://doi.org/10.1038/s41398-018-0213-8.

Rohani, D. A., Sorensen, H. B. D., & Puthusserypady, S. (2014). Brain-computer interface using P300 and virtual reality: A gaming approach for treating ADHD. *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC 2014*, 3606–3609. https://doi.org/10.1109/EMBC.2014.6944403

Ruiz-Manrique, G., Tajima-Pozo, K., & Montañes-Rada, F. (2015). Case Report: "ADHD Trainer": the mobile application that enhances cognitive skills in ADHD patients. *F1000Research*, *3*, 283. https://doi.org/10.12688/f1000research.5689.3.

Ryan, G. S., Haroon, M., & Melvin, G. (2015). Evaluation of an educational website for parents of children with ADHD. *International Journal of Medical Informatics*, *84*(11), 974–981. https://doi.org/10.1016/j.ijmedinf.2015.07.008.

Schoenfelder, E., Moreno, M., Wilner, M., Whitlock, K. B., & Mendoza, J. A. (2017). Piloting a mobile health intervention to increase physical activity for adolescents with ADHD. *Preventive Medicine Reports*, *6*, 210–213. https://doi.org/https://doi.org/10.1016/j.pmedr.2017.03.003.

Schuck, S., Emmerson, N., Ziv, H., Collins, P., Arastoo, S., Warschauer, M., … Lakes, K. (2016). Designing an iPad app to monitor and improve classroom behavior for children with ADHD: ISelfControl feasibility and pilot studies. *PLoS ONE*, *11*(10), 1–13. https://doi.org/10.1371/journal.pone.0164229.

Shin, M. S., Jeon, H., Kim, M., Hwang, T., Oh, S. J., Hwangbo, M., & Kim, K. J. (2016). Effects of smart-tablet-based neurofeedback training on cognitive function in children with attention problems. *Journal of Child Neurology*, *31*(6), 750–760. https://doi.org/10.1177/0883073815620677.

Sibley, M. H., Comer, J. S., & Gonzalez, J. (2017). Delivering Parent-Teen Therapy for ADHD through Videoconferencing: a Preliminary Investigation. *Journal of Psychopathology and Behavioral Assessment*, *39*(3), 467–485. https://doi.org/10.1007/s10862-017-9598-6.

Simons, L., Valentine, A. Z., Falconer, C. J., Groom, M., Daley, D., Craven, M. P., … Hollis, C. (2016). Developing mHealth Remote Monitoring Technology for Attention Deficit Hyperactivity Disorder: A Qualitative Study Eliciting User Priorities and Needs. *JMIR MHealth and UHealth*, *4*(1), e31. https://doi.org/10.2196/mhealth.5009.

Steiner, N. J., Frenette, E. C., Rene, K. M., Brennan, R. T., & Perrin, E. C. (2014). In-School Neurofeedback Training for ADHD: Sustained Improvements From a Randomized Control Trial. *Pediatrics*, *133*(3), 483–492. https://doi.org/10.1542/peds.2013-2059.

Tse, Y. J., McCarty, C. A., Stoep, A. Vander, & Myers, K. M. (2015). Teletherapy Delivery of Caregiver Behavior Training for Children with Attention-Deficit Hyperactivity Disorder. *Telemedicine and e-Health*, *21*(6), 451–458. https://doi.org/10.1089/tmj.2014.0132.