

An Educational Application of Online Games for Learning Difficulties

M. Margoudi, Z. Smyrniou

Abstract—The current paper presents the results of a conducted case study. During the past few years the number of children diagnosed with Learning Difficulties has drastically augmented and especially the cases of ADHD (Attention Deficit Hyperactivity Disorder). One of the core characteristics of ADHD is a deficit in working memory functions. The review of the literature indicates a plethora of educational software that aim at training and enhancing the working memory. Nevertheless, in the current paper, the possibility of using for the same purpose free, online games will be explored. Another issue of interest is the potential effect of the working memory training to the core symptoms of ADHD. In order to explore the abovementioned research questions, three digital tests are employed, all of which are developed on the E-slate platform by the author, in order to check the levels of ADHD's symptoms and to be used as diagnostic tools, both in the beginning and in the end of the case study. The tools used during the main intervention of the research are free online games for the training of working memory. The research and the data analysis focus on the following axes: a) the presence and the possible change in two of the core symptoms of ADHD, attention and impulsivity and b) a possible change in the general cognitive abilities of the individual. The case study was conducted with the participation of a thirteen year-old, female student, diagnosed with ADHD, during after-school hours. The results of the study indicate positive changes both in the levels of attention and impulsivity. Therefore, we conclude that the training of working memory through the use of free, online games has a positive impact on the characteristics of ADHD. Finally, concerning the second research question, the change in general cognitive abilities, no significant changes were noted.

Keywords—ADHD, attention, impulsivity, online games.

I. INTRODUCTION

THE diagnoses of individuals and especially children with ADHD have increased in the past few years. One of the core characteristics of ADHD is a deficit in working memory ability. Although a plethora of studies have been conducted on working memory training through the use of different educational software, the current study focuses on an alternative aspect. The study aims at the investigation of the use of already existent, free-access to all, online games for the same purpose. In more detail, the research questions investigate the impact of training working memory for two core symptoms of ADHD, attention deficit and impulsivity, as well as the impact for the general cognitive abilities of the individual. To this direction, three distinct digital evaluation

M. Margoudi was with the National and Kapodistrian University of Athens (UOA), Greece. She is now with the École Polytechnique Fédérale de Lausanne (EPFL) (phone: 0041-767389428; e-mail: maria.margoudi@gmail.com).

Z. Smyrniou is with the National and Kapodistrian University of Athens (UOA), Greece (e-mail: zsmyrniou@ppp.uoa.gr).

tools were developed by the author, by utilizing the “E-Slate platform”. In the following chapters the details concerning the procedure followed to this goal is described.

II. THEORETICAL FRAMEWORK

A. Learning Difficulties and ADHD

During recent years there is a rising research interest on individuals that are facing various learning difficulties. The exact cause of learning difficulties is not yet fully known to researchers. Nevertheless, it is known that the disorders linked to learning difficulties are inherent to the person and attributed to a dysfunction of the central nervous system and may persist throughout the life of the individual [1].

Attention Deficit Hyperactivity Disorder (widely known as ADHD) is a neurodevelopmental disorder attributed to the spectrum of learning difficulties. It is associated with the maturation of the nervous system and it appears with a constant course and specific cognitive dysfunctions. ADHD is a usual behavioral disorder during childhood, but it may persist during adulthood [2].

The most common symptoms of ADHD are hyperactivity, impulsivity and attention deficit and it is estimated that between 4 and 10 percent of the population has it. Possible coexisting disorders are specific learning difficulties and relationship management problems, either within the family, or with peers. A large percentage of individuals with ADHD continue to experience symptoms in adolescence and even in adulthood [3].

The indications of the presence of ADHD are difficult to be identified because of their close relation to the developmental stage of each individual. According to the latest edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) the symptoms must be observed in two different contexts, for a period of time of at least six months long and they also must exceed the degree of appearance of the rest of the peers [4].

There are three identified subtypes of ADHD, based on the intensity of the symptoms: a. mainly inattention type, b. mainly hyperactive-impulsive type and c. combined type, where the criteria for both other types are fulfilled [4].

B. Cerebral Functions Related to ADHD

The neurodevelopmental disorders linked to ADHD occur early in life and are mainly associated with disorders in the development of the nervous system. The main symptoms are deregulation of behavior, deficit in executive functions, like inhibitory control, working memory and delayed aversion, which translates into a preference for smaller, immediate

rewards, rather than bigger but delayed ones [2].

It is estimated that 85% of individuals with ADHD continue to experience symptoms during adolescence. More specifically, the low school performance of individuals with ADHD is, mainly, due to their difficulty of completing school assignments and their poor social skills that often lead to conflicts with parents. It should be also noted that the combination of ADHD with adolescent immaturity may lead to involvement with high-risk activities [2].

A review of the relevant literature makes evident the fact that a topic studied in depth, in relation to ADHD, is working memory. The majority of the studies indicate that individuals diagnosed with ADHD demonstrate a deficit in working memory [7]. Among other deficits associated to ADHD, working memory deficit is considered to be a central one and it is suggested that it is associated with a reduced function of the frontal lobe [5].

In general, ADHD is closely linked to deficits in executive functions, which is a generic term for the systems involved in the control of high-level cognitive processes, required in behavior in conjunction with the frontal lobes. To summarize, ADHD is characterized by severe disorders in inhibitory control and working memory [6].

Working memory is defined as the individual's ability to hold information in mind, while in the same time being able to handle them [21]. Even though the capacity of working memory is limited and information can be retained just for a few seconds, working memory is linked to the ability of vocabulary learning, reading and understanding a language, taking notes, writing, reasoning and complex learning [7].

C. Digital Technologies for ADHD

A general classification of ADHD management methods could involve pharmaceutical and non-pharmaceutical methods. The significant restrictions and complications that may be caused through the application of pharmaceutical solutions stress even more the importance of the presence of alternative, effective, non-pharmaceutical solutions [8].

The spectrum of non-pharmaceutical solutions for ADHD consists of a plethora of methods. Widely applied practices are psychological therapy, cognitive behavioral therapy (CBT), interpersonal psychotherapy, family therapy, school interventions, social skills' training and parental management training [9].

A form of therapy, receiving great amount of attention by the researchers, is computer-based attention training. Some of these systems are based on neurofeedback, which tracks and enhances behaviors associated with attention's increase, as indicated by specific brainwave patterns. Other systems use a standard computer format (SCF), which is a cognitive training approach aiming at improving attention and concentration of individuals through a series of challenges [3].

Studies based on neuroimaging show that training has a significant impact on neuronal activity and particularly in areas of the brain associated with working memory [6].

Several commercially available attention training systems utilize a standard computer, mouse and keyboard format. The

individual engages in a series of interactive exercises that aim to improve attention, problem solving skills and working memory. Gradually, by training, the individual is able to complete the tasks in greater ease and speed and reduced impulsivity and thus achieve higher scores and move on to levels of higher difficulty [3].

There are indications that video games may contribute to the reduction of the symptoms of ADHD. The first video game treatment for children with ADHD was realized by Pope and Bogart [10] and it was named "Extended Attention Span Training (EAST)". It was actually a modified program used by NASA in order to evaluate the commitment of its pilots while they used automated flight management systems [11].

III. THE EVALUATION TOOLS

For the purposes of this study, three distinct digital tools were designed and implemented, in order to act as assessment tools before and after the main intervention. For the realization of these tools the "E-Slate platform" was utilized. "E-Slate" is a source for prefabricated educational software and also works as a design and development software tool. The products of this platform are called microworlds and consist of computing environments that incorporate a coherent set of scientific concepts and relations [12].

In more detail, the three aforementioned tools base their structure and content to already existent tools, either available online, or for commercial use. These tools are "Raven's test", Stroop's test" and "Sustained Attention test".

The first tool is based on "Raven's Progressive Matrices", which is a standardized intelligence test. It consists of visual, geometrical analogy problems, presented in a matrix of geometrical shapes. Each time, an entry in this matrix is missing and the correct answer should be selected from a set of responses. It is a widely used test, which uniqueness lies on the fact that it focuses on visual problem solving and more particularly, on visual similarity and proportion issues [13]. We should note that there are three available versions of Raven's Progressive Matrices: a. Standard, b. Standard Plus and c. Colored. In the current study the standard version was utilized. The advantages of this version are that it can be used with individuals of all ages and also requires a limited amount of time from the user to finish it [14].

The second tool used is inspired from "Stroop's Color Interference Task". It is one of the most widely studied examples of cognitive psychology. Its content is relevant with the classical behavioral reaction of prolonging his response time when naming the color of the word, when the meaning of this word and its display are incompatible [15]. During recent years, the use of this test is facing an increase as a diagnostic and research tool for the control of the executive function, after an injury of the frontal lobe or a psychiatric disease, such as depression and schizophrenia [16]. In this study, the model of Klingberg et al. [17] was followed. In more detail, "Stroop's test" was used for estimating the impulsivity levels of the user. To this direction, a series of words were provided, each of which named a different color. Nevertheless, the name of the color and the actual color of the word do not always

match. For example, a word may spell “green”, but its actual color could be yellow. The user is asked to read aloud the actual color of the word [17].

Finally, the third activity is “Sustained Attention test” which consists of a version of a “Continuous Performance test” (CPT). A CPT was first developed by Mackworth in order to examine the performance of radar operators, but its initial purpose was altered by researchers in the following years who used it in order to identify deficits in neuropsychological performance. Finally, the CPT was used by ADHD researchers in an attempt to measure the attention levels of the user [18]. The structure and content of the “Sustained Attention test” used in our study is derived from the “Cogtest” online platform [22] that encompasses neurocognitive tests with research purposes.

IV. METHODOLOGY

A. Purpose and Objectives

The purpose of this case study was to investigate the feasibility of training working memory and also its impact to the core symptoms of ADHD. In more detail, the hypothesis investigated referred to whether the training of working memory through the use of free online digital tools was possible and also if it has a positive impact on ADHD symptoms and finally if it contributes to the improvement of an individual’s cognitive abilities. More specifically, the objectives pursued by the study focused on the effects of working memory’s training on the core symptoms of ADHD, through the use of free, online games. The study also focused on the possible effects of this intervention to the general cognitive abilities of an individual and their possible link to working memory. Another objective of the study, that won’t be elaborated in the current paper, referred to the role and significance of scaffolding activities carried out before and after the intervention and the appropriate scaffolding type for this type of activities.

B. The Research Questions

The research questions that are going to be elaborated in the current paper are the following two:

- What is the effect of working memory’s training, through the use of free online games, to the core symptoms of ADHD: attention and impulsivity deficit?
- What is the effect of working memory’s training, through the use of free online games, to the general cognitive abilities of an individual?

Aiming at addressing the aforementioned research questions and based on relevant theoretical frameworks, appropriate analysis categories were created that operated as criteria for the categorization of the collected data.

C. The Method

The described study follows a qualitative research approach, based on interpreting human behavior in relation with various situations towards the construction of social reality. It is a case study and in more detail an individual case study. In order to ensure the validity of the study the collected

data were triangulated, while concerning its reliability, it was ensured through the use of an observation method, where the researcher acted like a standard tool, as well as by recording all the activities that took place [19].

D. Time and Space Framework

The described case study was conducted in the residence of the participant, serving reasons of familiarity with the environment. The venue was appropriately organized in order to reduce external distractions, either visual or audible, and ensure the participant’s maximum performance during the activities of the study.

The study was conducted during June 2014 and lasted for a week (seven days). In more detail, the duration of the main intervention was five days, for fifteen minutes per day. The rest two days, one before and one after the main intervention, the pre and post-tests took place accordingly and lasted for one hour per day.

E. The Sample

For the purposes of the study, a thirteen year-old, female student participated. The student was officially diagnosed with ADHD in 2011. She was familiar with the basic functions of a PC, but it was her first encounter with “E-Slate” software’s environment. She participated voluntarily and had no prior experience of participating in any kind of research activities.

The researcher was present during the pre and post phases of the activity mainly with the role of the observer, but also occasionally supported the participant in terms of enabling the flow of the activities and the use of “E-Slate” tools.

F. Data and Analysis

The data used in the research analysis originated from the transcript of the recording of the study’s activities and in more detail from the pre and post-test phases, the observations of the researcher and the results from the three tests.

Due to the nature of the described data, the Content Analysis method was considered to be the most appropriate one. Following a mixed research approach that combined both qualitative and quantitative data, the focus of the study was directed to the significance of each unit of analysis to the final purpose of the study, as well as to the significance of the frequency of each unit of analysis.

V. THE COURSE AND PHASES OF THE STUDY

On the first day of the study, the researcher dedicated ten minutes in explaining the procedure to be followed, the activities and the manipulation of “E-Slate” platform.

At first, the pre-test phase was conducted, during which the participant completed the three provided tests, described in previous sections of this paper (“Raven’s test”, “Stroop’s test” and “Sustained Attention test”).

For the realization of the second phase of activities, the main intervention, the participant was requested to visit on a daily basis, for the following consecutive five days, certain websites, each of which provided a different online game for memory training.



Fig. 1 Working Memory Training Game

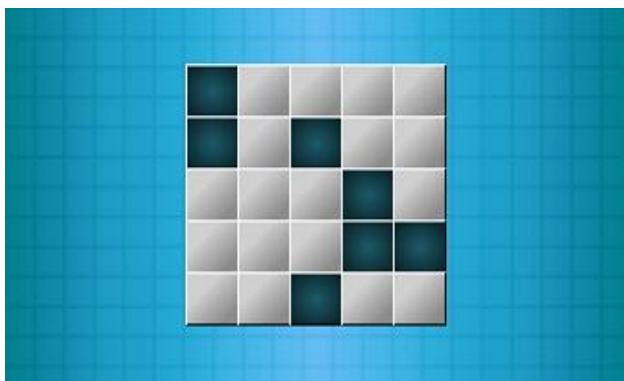


Fig. 2 Spatial Memory Skills Training Game

In more detail, the first game was developed by “Cogmed” (Fig. 1) and aimed at improving the working memory skills of the player [23]. The main purpose of the player was to remember the exact order of several procedures and successfully repeat them. The second online game was provided by “Memory-Improvement-Tips” platform and aimed at training the player’s spatial memory skills (Fig. 2). Analytically, the player has a brief visual access to a certain motive of tiles, which soon disappears. The purpose of the game is to recreate this specific motive [24]. The third and final online game was developed by the same platform (“Memory-Improvement-Tips”) and based its structure to the player’s ability to concentrate (Fig. 3). In detail, after having a brief visual contact with several pair of cards, they are placed upside down with the final goal of the player identifying as many of them as possible [25].

During the third phase of the activities, the post-test phase, which took place the seventh day of the intervention, the participant was asked to complete, once more, the three tests of phase one (“Raven’s test”, “Stroop’s test” and “Sustained Attention test”).

VI. RESULTS

The data collected from the qualitative analysis of the discourse during the study’s activities, between the participant and the researcher, were then appropriately coded and registered in analysis’ tables in order to reach quantitative

conclusions regarding the research questions of the study. Following the comparison between the pre and post-test activities the following results were drawn in accordance with the posed research questions:

A. Results on Attention Deficit and Impulsivity

The concentration of the participant was greatly improved. More specifically, a parallel increase of the participant’s interest was noted towards the process in which he had to engage to and a decrease of the difficulties he faces towards the completion of the activity.

Also, it should be noted that after the main intervention the occasions where the attention of the participant was distracted were mainly due to environmental factors and not to the intrinsic characteristics of the participant.

The occurrence of inappropriate behaviors, such as beginning of an off-topic discussion, or the manifestation of distress, as a form of impulsivity, also seem to have been considerably reduced after the main intervention.

However, it should be noted that behaviors indicating haste, such as hasty responses to the tests, have sharply risen after the main intervention, while behaviors that indicated that the participant was ignoring the instructions given were almost non-existent in the post-test phase.



Fig. 3 Concentration Ability Training Game

The results driven from both “Stroop’s test” and “Sustained Attention test” verify the abovementioned conclusions. In detail, the comparative results of the pre and post-test phases of “Stroop’s test”, for defining the levels of impulsivity, show that in the post-test phase the participant completed the test without making any mistakes. Concerning “Sustained Attention test’s” results, for the definition of attention deficit levels, we should note that in the second phase the participant managed to considerably limit wrong answers. Overall, in response to the research question about the effect of working memory training, through the use of free online games, to the two core characteristics of ADHD, we can conclude that it had a positive impact on both of them.

B. Results on General Cognitive Abilities

Concerning the effect of the intervention to the general

cognitive abilities of the participant it should be noted that no significant variation, between the percentages of correct and incorrect questions, was observed after the main intervention. Therefore, answering the second research question, on the effect of working memory training, through the use of free online games, to the participant's general cognitive abilities we conclude that the data of the current study do not indicate either a positive or a negative change.

C. Restrictions and Future Work

At this point we should clarify the need for further research in order to validate the results of the current study. The reason for this is dual and consists both to the limited number of participants and the short duration of the described case study. This is why we cannot generalize the results of the study to the general population. Therefore, in order to establish the validity and reliability of the study, the implementation of a similar study for a larger scale and for a longer period of time is suggested.

We should also point out that the current study doesn't examine one of the core characteristics of ADHD, which is hyperactivity. This is due to the lack, at the time, of appropriate tools that would allow the measurement of hyperactivity levels during the different phases of the study. Furthermore, it should be noted that the exploited screen recording tool presented a malfunction during a certain point of the study and caused a temporal discrepancy between the sound and the video presented. Finally, as a recommendation for future experimentations, the cross-analysis [20] of the results by two or more different researchers is proposed.

ACKNOWLEDGMENT

The author, M. Margoudi, would like to thank the participant of this case study for taking part and an excellent cooperation.

She would also like to thank Associate Professor at the University of Athens and co-author in this paper, Zacharoula Smyrnaiou, for the guidance and the support towards the completion of the presented study.

REFERENCES

- [1] Gaddes, W.H., Edgell, D. (1994). Learning disabilities and brain function: A neuropsychological approach, New York, Ed. Springer - Verlag, Third ed.
- [2] Koumoula, A. (2012). The course of attention deficit hyperactivity disorder (ADHD) over the life span. *Psychiatrike= Psychiatriki*, 23, 49-59.
- [3] Steiner, N. J., Sheldrick, R. C., Gotthelf, D., & Perrin, E. C. (2011). Computer-based attention training in the schools for children with attention deficit/hyperactivity disorder: a preliminary trial. *Clinical Pediatrics*, 50(7), 615-622.
- [4] American Psychiatric Association (APA) (2013) Diagnostic and statistical manual of mental disorders Fifth Edition (DSM-5®), Washington, DC: American Psychiatric Association.
- [5] Klingberg, T., Forsberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of clinical and experimental neuropsychology*, 24(6), 781-791.
- [6] Holmes, J., Gathercole, S. E., Place, M., Dunning, D. L., Hilton, K. A., & Elliott, J. G. (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology*, 24(6), 827-836.
- [7] Gomes, L. (2011). Attention and memory in boys with predominantly inattentive and combined subtypes of ADHD.
- [8] Trout, A. L., Lienemann, T. O., Reid, R., & Epstein, M. H. (2007). A review of non-medication interventions to improve the academic performance of children and youth with ADHD. *Remedial and Special Education*, 28(4), 207-226.
- [9] National Collaborating Centre for Mental Health (UK). Attention Deficit Hyperactivity Disorder: Diagnosis and Management of ADHD in Children, Young People and Adults. Leicester (UK): British Psychological Society (UK); 2009. (NICE Clinical Guidelines, No. 72.) Available from: <https://www.ncbi.nlm.nih.gov/books/NBK53652/>.
- [10] Pope, A. T., & Bogart, E. H. (1996). Extended Attention Span Training System: Video Game Neurotherapy for Attention Deficit Disorder. *Child Study Journal*, 26(1), 39-50.
- [11] Wilkinson, N., Ang, R. P., & Goh, D. H. (2008). Online video game therapy for mental health concerns: A review. *International journal of social psychiatry*, 54(4), 370-382.
- [12] Kynigos, C. (2007). Half-baked Logo Microworlds as Boundary Objects in Integrated Design. *Informatics in Education* 6, no. 2: 335-358.
- [13] Kunda, M., McGreggor, K., & Goel, A. K. (2009, October). Addressing the Raven's Progressive Matrices Test of "General" Intelligence. In AAAI Fall Symposium: Multi-Representational Architectures for Human-Level Intelligence.
- [14] Raven, J. (2000). The Raven's progressive matrices: change and stability over culture and time. *Cognitive psychology*, 41(1), 1-48.
- [15] Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of experimental psychology*, 18(6), 643.
- [16] Liotti, M., Woldorff, M. G., Perez III, R., & Mayberg, H. S. (2000). An ERP study of the temporal course of the Stroop color-word interference effect. *Neuropsychologia*, 38(5), 701-711.
- [17] Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., ... & Westerberg, H. (2005). Computerized training of working memory in children with ADHD-a randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, 44(2), 177-186.
- [18] Epstein, J. N., Erkanli, A., Conners, C. K., Klaric, J., Costello, J. E., & Angold, A. (2003). Relations between continuous performance test performance measures and ADHD behaviors. *Journal of abnormal child psychology*, 31(5), 543-554.
- [19] Robson, C. (2007). How to do a research project: a guide for undergraduate students. Blackwell.
- [20] Smyrnaiou, Z., Petropoulou, E., Margoudi, M. & Kostikas, I. (2014). Patternization of an Inquiry-based design process for the construction of a structurally sound educational tool: The paradigm of a secondary development tool negotiating scientific concepts. Manuscript submitted for publication.
- [21] Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.
- [22] Cogtest. (n.d.). Retrieved June 24, 2015, from http://www.cogtest.com/tests/cognitive_int/sa.html
- [23] About Working Memory. (n.d.). Retrieved June 24, 2015, from <http://www.spaceminespatrol.com/>
- [24] Pattern Memory - Free Brain Game. (n.d.). Retrieved June 24, 2015, from <http://www.memory-improvement-tips.com/pattern-memory.html>
- [25] Free Concentration Card Game - Flipped Out. (n.d.). Retrieved June 24, 2015, from <http://www.memory-improvement-tips.com/concentration-card-game.html>.