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Using mobile apps to treat ADHD in children

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Abstract

People are turning to the digital world for answers to challenges in their daily lives as the number of mobile applications increases. People with impairments now have equal opportunities for education because of technological advancements. The majority of their time is now spent on mobile devices by youngsters. Therefore, using mobile applications to solve their issues would be pretty successful. Mobile learning, also known as e-learning programs that utilize mobile devices, can be used as therapeutic methods to enhance executive functioning and quality of life. Additionally, increasing the frequency of exercising cognitive and metacognitive task skills increases motivation in both children and teenagers. Moreover, the understanding and retention of the presented information might be aided by the audiovisual stimuli offered through smartphone applications. As a result, kids with ADHD may be crucial learning sources. Therefore, to enhance the quality of life for children with ADHD, the current study explores the function and efficacy of mobile applications.

Keywords

Attention Deficit Hyperactivity Disorder (ADHD), Social/Emotional Development, ICTs, Mobile Applications, Learning, Physical activity, Metacognition.

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Introduction

One of the most frequent neurological disorders between children and youths is Attention Deficit Hyperactivity Disorder (ADHD). Yet, its nature is still complex and a general understanding of its mechanisms has still not been achieved. ADHD's main symptoms are lack of attention and impulsivity, which are due to a dysfunction in those brain areas that manage specific abilities, called executive functions. Executive functions such as short-term memory, flexible thinking, and self-regulation are essential for an individual's socio-emotional health (Drigas & Driga, 2019). Also, cognitive ability is an established predictor of school success, whereas a child's reduced school performance due to personal shortcomings seems to contribute to low self-esteem (Karabatzaki et al., 2018). Early control and development of these skills lay the foundation for attention, organizational skills, selective focus on tasks, emotion control, and self-assessment (Drigas & Driga, 2019). Self-regulation constituting a critical area in which children with ADHD have difficulty with is also related to emotional intelligence. Emotional intelligence is the steering wheel for sensing, thinking, learning, problem solving and decision making. It also emphasizes the features of self-control, like the individual's capacity to slow down instant gratification, tolerate irritations, and regulate impulses (power of the ego).

In their research, Drigas & Papoutsi (2018) propose a structured model for the intervention of emotional intelligence, consisting of hierarchical levels that indicate the progressive development of an individual. This model can have practical applications as a treatment tool for special education, interpersonal relationships, as also any other aspect of life. More specifically, these levels relate to receiving and recognizing emotional stimuli, to self-knowledge, self-management, empathy, social skills, and self-actualization. According to Maslow's theory, self-actualization is the highest realization of personal potential, self-fulfillment, and the pursuit of personal well-being (1943;1987). Another studies by Drigas & Mitsea (2020;2021) that proposes a multilevel metacognition model argues that attention is at the "heart" of metacognitive skills and participates in processes such as selecting, filtering, suspension, processing, storage, retrieval, prediction, monitoring, adjustment, adaptation, recognizing, distinguishing, remembering, and knowledge transformation. According to this model, each level describes a higher-ranking control system that indicates the individual's metacognitive development. The progression from the lowest to the greatest levels of metacognition entails a shift to more complex kinds of self-awareness and self-observation, which leads to the formation of a more sophisticated control system.

Only when individuals develop these pillars of metacognition will they be able to incorporate the appropriate cognitive and socio-emotional skills that will enable them to integrate in the social environment. Metacognition is the most valuable tool in self-learning, self-development and self-healing. It should therefore be the cornerstone of a special intervention program that promotes holistic learning. Medication is considered a first-choice treatment to reduce the symptoms of ADHD, through the development of metacognitive skills. However, it has several disadvantages due to the side effects caused and the risk of addiction. On the other hand, intervention tools such as mobile applications with the use of new technologies have proved to be just as effective.

ADHD and Cognitive Skills

Ruiz-Manrique et al. (2014) studied the case of a 10-year-old child with attention deficit hyperactivity disorder (ADHD) and video game addiction. The child was medicated with methylphenidate (40 mg per day) and began attending a new method of cognitive training based on mobile applications called TCT (Tajima Cognitive Treatment). More specifically, the "ADHD Trainer" application was designed to enhance cognitive skills such as attention, working memory, processing speed, calculation ability, reasoning, and visual-motor coordination. The purpose of this study was not only to highlight that regular cognitive training on smartphones in children with ADHD can improve some of their cognitive deficits, but also to act as a treatment for video game addiction.

Before treatment, parents complained about an intense video game addiction, reporting 4 hours of daily use. This affected the child's social interaction, causing poor school performance. In light of this, the child performed daily cognitive practice with the above mentioned app. During the first month, he was allowed to play the game for a maximum of 4 hours per day, as no symptoms of addiction (tolerance, withdrawal, or cognitive impairment) were observed. The average number of hours the child played the video game was 1 hour per day. Over the next few months, the goal was to play the game for about 10 minutes daily (Ruiz-Manrique et al., 2014).

The child's behavioral and academic performance was rated before and after the implementation, with the *Conners Parent and Teacher Rating Scales* (Conners, 1973) rating scales and the *School Situations Questionnaire, (SSQ),* (Barkley, 1987). In addition, attention was rated with *CPT* (Conners Continuous Performance Test) (Conners, 1995). In less than two months, the abuse of video games decreased significantly, narrowing their use down to weekends and always for periods that did not exceed 4 hours in total. Also, the school and the family reported significant improvement in the child after six months of TCT cognitive training (Ruiz-Manrique et al., 2014).

Moëll et al. (2015), evaluated an online intervention in adults with ADHD aimed at improving organization and attention skills with the help of smartphone application, called "Living Smart". Participants (n=57) were adults over 18 years of age in Sweden with severe disorganization and inattention problems. As assessed by questionnaires and telephone interviews, they were randomized between an intervention group (n=29) and a control group (n=28). The 6-week intervention included support from a supervisor in finding a routine to organize their daily life with the help of a smartphone. At the end of the intervention, four supervisors assessed the change in the participants' organization and inattention difficulties using an adapted version of the *Clinical Global Impres-*

sions-Improvement scale (Kadouri et al., 2007). In order to assess attention and hyperactivity, the *Adult ADHD Self-Report Scales* (ASRS) was used (Kessler et al., 2005). To measure symptoms of depression and anxiety, the scale *HADS-A* was employed (Lispers et al., 1997). Finally, to examine the quality of life and the general level of functioning *Sheehan Disability Scale (SDS)* (Sheehan, 2008) was used.

The lessons have been adapted to fit iPhone and Android smartphones. Initially, participants accessed the online platform that included course materials and a messaging system to communicate with the supervisor. During the course, all participants used "Google Calendar" as their primary tool. Some parts of the diary could be shared with the course supervisor if the participant wished. Learning to use the to-do list application "G-tasks" was also crucial in the intervention. In addition, to these core and mandatory apps, several other apps targeting specific areas of ADHD were presented and used voluntarily by participants. "Evernote" is an application for taking notes and remembering thoughts and ideas and was used as a supplement to G-tasks. "N-back" has been used to train working memory and has previously shown promising results in this area (Studer et al., 2009). "SimplyNoise" produces sound which improves concentration among adults with ADHD (Sikstro and Smart, 2007). Two web browsers, "Stayfocusd" and "Leechblock", were introduced to block distracting websites. General management applications such as "Dropbox", banking, and mobility were also introduced. At the end of the course, participants were given homework on the techniques and applications learned.

Participants in the "Living Smart" group showed a significantly more remarkable reduction in the ASRS inattention subscale than the control group. Additionally, the HADS depression scale and the Hyperactivity subscale of the ASRS showed significantly greater improvements. No significant changes were found for the other assessment domains related to anxiety, stress, and overall functioning. Participants were generally happy with the progress of the courses and reported that it was a suitable intervention. Some people said they wanted more guidance, while others reported that the course gave them a better understanding of their shortcomings and found it helpful (Moëll et al., 2015).

The study by Butt et al. (2020) aimed at motivating children to maintain their interest in learning using the mobile app "Say-it and Learn". Five children with ADHD with an average age of 6.4 years participated in the research. Afterwards, interviews were conducted with the parents and caregivers of these children to assess the level of satisfaction and acceptance of the learning content of the application. "Say-it and Learn", is an application with facial recognition techniques. Kids enter their name at startup and choose to connect with their face. The application consists of three main sections. The first concerns learning letters in English, the second learning basic exercises related to mathematics and the last section aims at learning shapes. In addition to the tasks, the application offers tests for children to assess themselves on the topics they have learned. While using the application, interactive learning is maintained with melodious music which arouses children's interest. The application also reminds children of various healthy activities, e.g., drinking water and milk, eating nuts, reading books, and playing more. These reminder messages encourage children to be more active. In addition, the application includes various techniques and exercises for evaluating children's performance in these areas (Butt et al., 2020).

In the post-survey evaluation, all participants were asked questions and their responses were rated on a 5-Likert scale. The questions were about children's opinion of the app. All the children agreed that the app helped them learn new things. None of the children claimed that they would not use the app again, indicating that it was not boring. Instead, they admitted that it was very useful for learning and engagement. Furthermore, the counselor involved in this process reported that the background music was quite relaxing and beneficial for the children's learning. In the following research phase, parents and caregivers were asked to provide the app to children for the next six days under supervision. On the seventh day, they were asked about the overall change it brought about in their children. All families responded positively and explained that their children improved in the individual lessons offered by the app. They also reported that they were satisfied and they appreciated the design and functionality of "Say-it and Learn". The results showed that the application is interesting and attractive, while at the same time it improves the learning ability of children with ADHD, compared to traditional teaching methods. All ADHD professionals and specialists who tested the app agreed that "Say-it and Learn" is an app that will be beneficial to all children with ADHD in their school activities, clinics, schools, and houses (Butt et al., 2020).

ADHD and General Health

Tobias et al. (2019) report the results of a mobile application, which they called "MOBERO", administered for four weeks to 13 children with ADHD and their families. Its purpose was to contribute to the establishment and change of family practices in their children's morning and bedtime routines. Recent research points to the potential of technology in improving and educating adults about their sleep habits (Jared et al., 2012; Matthew et al., 2012). "ShutEye" (Jared et al., 2012) uses an approach where the mobile phone wallpaper provides information on the impact of certain behaviors on sleepsuch as eating and drinking at different times. Likewise, the "Lullaby system" (Matthew et al., 2012) uses an array of environmental sensors and a mobile screen to educate and assist users in creating optimal conditions for sleep. Researchers have also recently begun to report mobile applications for children with ADHD (Tobias & Kaj, 2015), including "TangiPlan" (Orad et al., 2014), "ChillFish" (Tobias & Mads, 2016), "BlurtLine" (Dorothé & Saskia, 2015) and "CASTT" (Tobias et al., 2015).

"TangiPlan" is a system that helps children complete their morning routines as a way to improve their executive functions (Orad et al., 2014). ChillFish (Tobias & Mads, 2016) is a biofeedback game designed to help children with ADHD do calm breathing exercises. By breathing through a fish on

the mobile screen, the player controls the movement of his character and with a strategy of placing stars (points in the game) he is encouraged to breathe at a relaxing pace. "BlurtLine" (Dorothé & Saskia, 2015) and "CASTT" (Tobias et al., 2015) are examples of apps that, unlike "TangiPlan" and "ChillFish", focus on providing sensor-based assistance to children with ADHD in school contexts. For example, "BlurtLine" is designed to help the child avoid impulsive speech by using an interactive chest strap that acts both as a sensor (detects impending impulsivity) and an intervention device providing tactile feedback (Dorothé & Saskia, 2015). Instead, "CASTT" focuses on helping children with ADHD regain and maintain attention during school lessons. CASTT relies on sensors that detect when the child has lost their attention and help them regain it (Tobias et al., 2015).

The app in the present study, called "MOBERO", alerts parents to start a bedtime routine approximately 15-20 minutes before the child is expected to go to sleep, which is discussed and agreed upon with the parent before they start using the app. The parents' routine includes airing the child's bedroom, preparing the child's pijamas and notifying the child about the upcoming bedtime. These activities intend to provide optimal conditions for sleep. After parents complete the bedtime routine, "MOBERO" displays a 15-minute countdown timer, which alerts the child to begin the routine. In addition, all 13 families completed a customized questionnaire (*MOBERO-Q*) before and after the intervention period and one month after the completion of the intervention period. The questions in the *MOBERO-Q* were related to the child's habits and activities around bedtime. All responses were recorded on a five-point Likert scale (1-5). After one month of implementation, "MOBERO" significantly reduced parents' frustration levels during the bedtime routine. They also reported that their child was more independent and had fewer conflicts around sleep (Tobias et al., 2016). These findings were based on an analysis of parents' daily ratings during the intervention. In addition, an improvement was observed in children's sleep habits based on a validated sleep screening questionnaire (Owens & McGuinn, 2000) and a reduction in ADHD symptoms based on the ADHD Rating Scale (ADHD-RS) (Douglas et al., 2001). The study suggests that "MOBERO" supported families in establishing healthy family practices, which were still observable one month after the implementation. All the above proved that "MOBERO" helped during the two-week intervention period and provided families with techniques they continued to benefit from even after the technology was no longer available (Tobias et al., 2019).

In their literature, Spachos, Chiazzasse, Merlo, Doherty, Chifari & Bamidis (2014) studied the applications for mobiles that are most often used as interventions for children with ADHD; they also studied the WHAAM mobile application and its usefulness. Mobile health (m-health) has become a critical subset of e-health due to the hardware capacity of smartphones that enables e-health functions in mobile applications (Liu et al., 2011). Of the mobile applications [69, 70], others function as informational and educational tools, while others help managing and tracking ADHD symptoms or even facilitate diagnosis. The WHAAM application allows behavior monitoring in a SMART way through creating a network of people involved in childcare and enabling data collection. The collected data is then visualized and assessed by the health professionals involved, enabling the planning and scheduling of the intervention. Furthermore, the WHAAM application provides tools for assessing the intervention's effectiveness (Alves et al., 2014). Many other applications have been developed; the ADHD Treatment Researcher (Vermont Behavioral Solutions, 2011) is an Android application that provides access to recent ADHD faculty developments, including published research, recent clinical trials, books, medical videos, events, forums and more. The "You Can Handle Them All" app (The Master Teacher® (2011) has been designed to help parents or educators manage behavior problems and is available for iPhone, iPad, iPod touch, and Android devices. The iBAA Behavior Assessment App (Future help designs, 2012) is suitable for psychologists allowing them to gather and summarize behavioral information; via iPhone or iPod touch it provides diverse observation methods, such as frequency and intervals of ADHD symptoms. Other applications have been designed by Apple such as "Behavior Assessment Pro" (Marz Consulting, 2011), to provide behavioral analysis through guided questions, and to plan further interventions along with reminders.

Powell, Parker, Robertson & Harpin (2017) studied the suitability of mobile applications for children with ADHD. With the advancement of technology [60, 61, 66, 67], ADHD can be successfully managed using applications especially designed for this population. Previous research by Xu et al. (2002) examined 19 studies evaluating the use of technology in students with ADHD in the age group of 4 to 19 years. The authors concluded that so far there is too little evidence that supports the effectiveness of such interventions. This study aimed to investigate the suitability of 10 applications for children and young people with ADHD, as well as for the doctors who work with them. For this purpose, mobile applications in the Apple iTunes Store and the Android Google Play Store in the United Kingdom were sought, and the top 10 applications, referring to children and young people diagnosed with ADHD, were selected for the study. The selections were made based on the apps' rankings defined by algorithms according to the number of downloads and ratings; the search term used was "ADHD". Five clinicians from a health service that treats children and young people with ADHD and five diagnosed children belonging to the age group from 6 to 17 years, took part in this study. During the study, the youngsters with ADHD used the applications and were then interviewed to share their feedback. Clinicians were also interviewed to share their views on how successful these applications were for this group (Powell et al., 2017). The clinicians considered that applications could be used to monitor the symptoms of children and adolescents with ADHD and that they have both a positive and a negative impact regarding their relationships with others. They also cared about additional factors, such as accessibility issues, how important it is for applications to take into account ADHD symptoms and the associated difficulties,

whether they are appropriate for all ages and whether they have customizable features, so that every user can relate. Also, two youngsters and clinicians noted that the applications weren't always reliable, as oftentimes they did not work properly or disconnected. Two youngsters also considered that having to pay for the applications was an obstacle, as they could not afford online payments. The youngsters and doctors alike, considered that applications should be fun, visually appealing, and use a language and characters to which children can relate, and receive rewards (Powell et al., 2017). Regarding the symptoms of ADHD, two participants claimed that the applications could be used to relax them (that is, to help their hyperactivity). They also noted that earning an instant reward during the game, such as coins, made them feel happy. Another participant noted that focusing on patterns made him relax. Likewise, clinicians believed that rewards were essential to attract users. One clinician believed that applications for ADHD have the potential to improve memory and inhibitions, thus aiming to reduce impulsivity. The young people suggested also that applications should be interactive, as they were less impressed and sometimes even frustrated with applications that did not involve interaction but only passive listening or watching. Doctors also suggested that applications could be utilized to track nutrition, mood, and ADHD symptoms, either as reminders or journals (Powell et al., 2017).

ADHD and Physical Activity

Schoenfelder et al. (2017) evaluated an innovative intervention using a mHealth mobile application, a Fitbit Flex and a Facebook group to increase physical activity in adolescents with ADHD. Physical activity improves cognitive performance, executive functions (i.e., working memory, behavioral inhibition), and ADHD symptoms in both children and adults (Gapin et al., 2011; Medina et al., 2010). Children with ADHD who received short physical exercise at school (e.g.,~30 minutes of games of moderate or intense exercise), showed an improvement in symptoms and general behavior during activities (Hoza et al., 2014). Physical exercise also affects mood regulation (Byrne and Byrne, 1993), reduces symptoms of depression and fatigue and improves motivation for people with ADHD (Fritz and O'Connor, 2016). However, little is known about how daily physical activity is affected such as walking (Ainsworth et al., 2011).

Mobile health apps (mHealth apps) are a rapidly growing and promising approach for interactive and personalized interventions which concern disease prevention (Patrick et al., 2008). Social media sites are also ideal for adolescent participation sharing of mHealth application data and connecting with other users as well. Over 80% of teenagers reported using social networking sites in 2013, with the majority using Facebook (FB) (Madden et al., 2013).This is used for multiple health promotion programs (Cavallo et al., 2012). A study of 30 teenagers who used a mHealth app, mobile activity tracker, and another group who used FB found that teens rated their participation and online interactions as enjoyable and beneficial (Pumper et al., 2015). The current study fills an important gap in the literature. It evaluates the feasibility, acceptability and effects of a behavioral intervention to increase daily physical activity for adolescents with ADHD using a Fitbit Flex (wearable activity tracker) and a FB group.

The research participants of Schoenfelder et al. (2017) were 11 adolescents aged 14-18 who had been diagnosed with ADHD. Similar to a previous pilot study (Pumper et al., 2015), participants were asked to wear a Fitbit for four weeks, sync the device twice a week, join a FB group and complete online questionnaires twice a week. The Fitbit Flex wristband collects physical exercise data, including steps, energy expended and distance traveled. Data syncs with the Fitbit mHealth app on a mobile device to provide data graphs and feedback towards personalized goal achievement. Adolescents were given a personalized goal for a week and joined a private FB group to interact with other participants and receive research information and encouragement.

ADHD symptoms were measured at baseline through parent and adolescent reports and throughout the study. Parents completed the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS) (Wolraich et al., 2003), in which they rated the severity of their adolescents' symptoms. Adolescents completed the VADPRS scales (Yen et al., 2007) and rated their mood using the Positive and Negative Affect Schedule for Children (PANAS-C) (Ebesutani et al., 2012). Over 30 days, there were significant increases in step counts and significant decreases in adolescent -and parent- reported inattentive and hyperactive/impulsive symptoms. However, there was no significant change in mood quality. Interviews demonstrated positive experiences with all survey items. Participants reported that the app increased awareness of activity levels and ADHD symptoms. The most common suggestions for improvement included increasing reminders, adding additional challenges or activity goals and using other social media. The Fitbit and Facebook mHealth intervention was helpful and highly accepted among adolescents with ADHD. It also appears to be a promising approach to help them increase physical activity and improve their health and functioning (Schoenfelder et al., 2017).

Young et al. (2014) designed a smartphone application called Snappy to control the core symptoms associated with Attention Deficit Hyperactivity Disorder (attention, impulsivity, and hyperactivity). The app was initially tested on 11 healthy adults over three sessions. In the current study, the AX-CPT test (Cohen et al., 1999) was integrated into a smartphone app for Android phones and then as a web App that also works on other platforms (e.g., iPhone). The app captures 3D movement data from sensors on the mobile which is used to measure the amount of physical activity during the CPT (Continuous Performance Test). Combined with sensor measurements. The test can provide information on the three ADHD behaviors (attention, impulsivity, and hyperactivity).

Participants were students and staff from the University of Nottingham (N=11). The application to implement the CPT-AX test was initially designed using the Eclipse IDE (Integrated Development Environment) for Java programming on an An-

droid platform with OS version 2.2 and above. A web application was then developed in JavaScript to implement the same functions. Overall, participants rated their experience using the app positively. Based on the feedback questionnaires given by the researchers, it was proved that the participants found the activity easy and comfortable via smartphone. Furthermore, most participants did not find using the app stressful and reported they were prompted to complete the task on time. Therefore, it is essential for further research to be conducted in order to study the effects of the application in a population of people with ADHD (Young et al., 2014).

Conclusion

Finally, we have to underline the role of digital technologies in education domain that is very productive and successful, facilitates and improves the assessment, the intervention and the educational procedures via Mobiles [61-66], various ICTs applications [67-95], AI & STEM [96-100], and games [101-105]. Additionally the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [106-132] as well as with environmental factors and nutrition [57-60], accelerates and improves more over the educational practices and results, especially for the students with ADHD.

Moreover, with the recent rise in smartphone usage and technological advancement, mobile software applications (Apps) are now being used in healthcare. Although software applications with related capabilities are also available on other devices, such as personal laptops, smartphones (and some smaller tablets) have the advantage of being mobile and available for immediate use by the owner. This makes it possible to keep in touch with people (be they friends, family, or healthcare professionals), access information or support over the internet, at any time of the day and in almost any location. This study aimed to review the literature on the use of mobile applications to identify and treatment the symptoms of ADHD. Mobile applications through the use of new technologies, are ready to play a significant role in therapeutic interventions, especially in treating ADHD symptoms. Children with ADHD exhibit a set of symptoms. The main symptoms of the disorder are inattention, hyperactivity, and impulsivity. According to Angelopoulou & Drigas (2021), memory and attention are linked when performing a task. Therefore, their role is crucial to treatment the cognitive functions of individuals with ADHD, since the higher the working memory level is, the longer is also the attention span. Additionally, children with ADHD are more prone to have working memory deficits. Because children with ADHD get bored quickly, it is essential to attract their attention on a continuous basis. Mobile applications make this possible because they require the child to remain focused and busy the entire time, and furthermore having all senses alert, which makes the intervention even more interesting for the user.

The discussion around the ADHD and corresponding rehabilitation methods is a reflection of the fluidity of our knowledge in these areas. Further research is needed to develop alternative therapies with the use of mobile applications, to improve these children's cognitive and metacognitive skills and enable them to integrate into the social environment.

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