



# Effects of E-Games on the Development of Saudi Children with Attention Deficit Hyperactivity Disorder Cognitively, Behaviourally and Socially: An Experimental Study

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**Abstract.** Attention Deficit Hyperactivity Disorder (ADHD) is a set of behavioural characteristics disorder, such as inattentiveness, hyperactivity and/or impulsiveness. It can affect people with different intelligent abilities, and it may affect their academic performance, social skills and generally, their lives. Usually, symptoms are not clearly recognized until the child enters school, most cases are identified between the ages 6 to 12. In the kingdom of Saudi Arabia (KSA), ADHD is a widely spread disorder among young children. Usually, they suffer from distraction and lack of focus, and hyperactivity, which reduce their academic achievements. As technology have been used in classrooms to facilitate the information delivery for students, and to make learning fun; some of these technologies have actually been applied in many schools in KSA with normal students, but unfortunately no studies were reported by the time of writing this paper. Specifically, there are no studies done for using any type of technology to help Saudi students with ADHD reaching up their peers academically. Because of that, our focus in this study is to investigate the effect of using technology, particularly e-games, to improve Saudi children with ADHD cognitively, behaviourally and socially. As well as evaluating the interaction between those children with the game interface. Thus, the investigation done through exploring the interaction of web-based games that runs on Tablets. The respondents are 17 ADHD children aged from 6–12 in classroom settings. The study involves focussing on interface of the games stimulate different executive functions in the brain, which is responsible for the most important cognitive capacities, such as: Sustained Attention, Working Memory, and Speed of Processing. Ethnographic method of research was used, which involved observing students' behaviour in classroom, to gather information and feedback about their interaction with the application. National Institutes of Health (NIH) tests were used in pre- and post- intervention to measure improvements in attention, processing speed and working memory. Students' test scores of main school subjects were taken pre- and post-intervention to measure enhancement in academic performance. Results show that using the application significantly improve

cognitive capacities for participants, which affected their academic grades in Math, English and Science, as well as its positive influence on their behaviour. In addition, the application's interface was found easy to use and subjectively pleasing. As a conclusion, the application considered effective and usable.

**Keywords:** ADHD · Cognition · HCI · Interactive · Games

## 1 Introduction

The first thing that parents think about when their child reach the age of understanding is searching for an educational institute that develops his/her knowledge and cognition so he/she can enjoy a bright and a successful future. They start their search by looking for a school that have a good reputation, with qualified teachers who have excellent educational experience in delivering information and skills development. Highly qualified teachers can identify the different levels of their students and classify them based on their understanding of the curriculum, through observation and assessment. In fact some of the students have learning issues that might affect their overall academic progresses and achievements.

Some of the issues that students could suffer from are caused by a behavioural condition called Attention Deficit Hyperactivity Disorder (ADHD). In simple words, the child with ADHD is hyperactive and sometimes impulsive; additionally he/she has attention problems, disorganized, and faces difficulties in finishing tasks. These symptoms could be reflected at school as difficulty in managing impulsive manners, not paying attention to teachers in classroom, poor skills in mathematics, and may struggle in reading [23]. ADHD was discovered a long time ago, but now it becomes easier to recognize on individual cases because of the awareness of some teachers and parents about it. We can say that it is widely spread among students especially from pre-school until 12th grade; this is supported by the findings of the American Psychiatric Association (APA) that acknowledges seven percent of school students are diagnosed with ADHD [13].

In school environment, the teacher has a significant role in recognizing the students with ADHD symptoms. On the other hand, teachers must be equipped with the knowledge for dealing with ADHD students using the best ways and strategies; to ensure providing those students with equal learning chances. It is recommended for teachers to improve their teaching/instructional methods as well as using different kinds of interventions for children with ADHD. Also, using certain methods for attracting their ADHD students' attention such as sounds, bright colours, animations, or images. Stimulate teamwork, theatrical presentations, choice making, peer tutoring, and create competition among students through contests and other creative methods [15].

In the last ten years, and with the advance utilization of technology in our daily life, schools and educational institutions introduced the latest technology in their educational systems as effective tools to assist in the academic development of their students. Laboratories are equipped with computers and devices, classrooms have been updated to include technical tools and devices to assist delivering information in an interesting way. Students uses different applications to understand mathematical problems, to produce creative short movies, to organize agenda and much more [16].

Some teachers and researchers admitted handheld devices and mobile phones to the classroom as new type of technological tools, which have proved their effectiveness in the development of skills of the average student. This came right after the emergence of several free and paid applications and games, some are educational and some are just for fun. The use of mobile devices and tablets in education allows students to access the information at any time and any place. Now, the teacher is no more the central source inside the classroom, instead he/she became the supervisor and the assistant in this open-source technical context [7].

It is good to utilize these technologies for ADHD students to improve some of their deficiencies, and to be a replacement of traditional strategies and interventions [6, 11, 17]. Few researches have been done in investigating the use of technologies and applications such as computer based games to improve ADHD students' academic performance. Additionally, more research should be done to explore whether the computer games could develop their skills, and solve some of the behavioural and cognitive problems for ADHD diagnosed children.

### 1.1 Statement of Purpose

In the kingdom of Saudi Arabia (KSA), ADHD is a widely spread disorder among young children, between the ages 6–12 years. Usually, they suffer from distraction, lack of focus, and hyperactivity, which put them back academically. They do not fully understand the lessons, due to lack of attention, but not because a mental illness. ADHD students are a little bit slower in delivering tasks on time than normal students; thus they can be frustrated to their teachers and parents.

Many suggested educational interventions and traditional approaches were applied in classrooms by educators, as we will demonstrate in literature. Even medical treatments are not desirable any more by parents. No denial of the positive effectiveness and improvement of some of these methods on the overall academic level of ADHD child, no recovery will be made rather than a smart way to let the child be more involved in class and to be more organized.

Now, technologies are considered an integral part of anyone life, especially children; they always use them whether they watch their favourite shows on TV, or play one of the entertaining or educational games on handheld devices. Many studies had brought the use of technology in classrooms [4, 5, 22]; to facilitate the delivery of information for students, to prompt collaboration among students with each other, and to make learning fun. Several types of technologies used to enhance and facilitate the educational process, such as the use of electronic boards, data display devices, speakers and microphones, teaching and learning applications using smart devices etc.

Some of these technologies were actually been applied in many schools in KSA with normal students, but unfortunately no studies were reported by the time of writing this paper. Specifically, there are no studies done for using any type of technology to help ADHD students, in KSA, to reach up their peers academically. Existing ADHD applications and games must be investigated, to verify their effectiveness toward improving disordered children.

The contributions of this work are as follows: (1) we investigated the effectiveness of an e-game, using tablets, on ADHD students; regarding improvement in their

abilities and skills, (2) as well as evaluated the usability, acceptability and adaptability of the game interface by observing children's behaviour while interacting with the game.

## 2 Related Work

Media, such as TV, movies, cartoons, video recordings, internet and games, has its major influence on the learning and behaviour of children [1]. So, an inactive environment may be unbearable for children who are hyperactive. In fact, children find it hard to sit still for a short period of time in classroom, and they involve in activities that demand listening and thinking [16]. Because of that, it is essential to incorporate technology in the learning process to grasp children attention, thus it will be reflected on their achievements. In our study we focus on the effect of using tools and games; to improve some of the weaknesses associated with ADHD disorder. Follows a review from literature on some of the tools, applications, and games that could help in the improvement of children with ADHD.

### 2.1 Tablets

Touch screen devices, or so called tablets, are powerful portable technologies that have been used recently in many fields, especially in learning. In the last few years, tablets were, and still, considered as productive learning tools used inside and outside school settings to assist education. They provide innovative use and direct access to a fortune of many resources. Many educational applications (apps) were developed with the help of teachers and educators for the transformation of learning [7].

One of the main benefits of tablets is that they support learning anywhere, anytime; that changes the traditional concept where the classroom is the essential learning place controlled by the teacher instructions during a typical school day [7]. These devices offer users an access to a wider and more variable source of learning resources and knowledge than what is offered in ordinary classrooms.

Many studies have proven the benefit of using tablets, such as the "iPad", in enhancing the learning procedure inside and outside school, in fact, these studies suggest to consider this technology not just as an "educational tool" rather than a "cognitive tool" [7]. They also provided the evidence that using iPads in classroom, by students, to improve engagement and enthusiasm, enhance collaboration and one-to-one tutoring, and improve learning outcome. For instance, a study by Wrońska [25], has verified that using an iPad-based tool helped ADHD students with reading comprehension. In this study, the iPad was selected to be used as the "tool" of experiment, owing to its "significant and very positive impact on learning" [8].

### 2.2 Applications and Games for ADHD

Most adults and even children find it very easy to download any application, from the App Store, on their tablets or mobile devices, by a single touch on the screen. Applications, such as games, health tracking, news, social media, educational and other

different categories, are considered now as essential needs of daily life. Over 3 million apps, for iOS (iPhone operating system) and android systems, are available to download in leading App Stores such as Apple and Google play, as published in the Statistics Portal in July 2015 [21]. Many applications were adopted in schools and institutions that provide educational tools and skills development, most of these apps are classified as ‘Education’ in the iTunes App Store [20]. Lots of developing companies are tending to design usable and effective educational applications, with taking into account certain design features that support diverse learners’ needs, even for students who have different learning experience either with disabilities or disorders [18].

Recently, technological tools via educational applications are integrated into school programs, by researchers and curriculum developers, to help students of all capabilities overcome learning obstacles, especially students with certain disorders and needs. Many applications have been found useful in facilitating the student’s school day and organizing his daily life [18]. Students with ADHD constantly need to be reminded, notified, instructed multiple of times; so, using alarm applications, for instance, would be helpful [9, 14]. Other applications and games were found to enhance the students’ academic level and develop some of their skills. After reviewing literature, Table 1 list some of the most popular applications and games used by children diagnosed with ADHD [3, 12, 17, 19, 24];

**Table 1.** Tablet applications for ADHD children from reviewed literature

Name of App	Type	Description
Homeroutines Alarmed-reminder timers inClass My Homework	Time Management	Create checklists Set alarm Reminders Notifications
Audio-notes recorder Event Countdown Audio note recorder-notepad Dragon Dictation Speak It To Me Talkulator Voice Dream Reader	Audio Application	Record notes Voice recognition Talking calculator Reading lists
Evernote Notability Knowtes MindNode	Note Taking Apps	Take notes and photos, generate to-do lists Record vocal reminders Support handwriting Word processing Document translator A drawing tool
iearnedthat-lite ireward	Behavioral Apps	Reinforce positive behaviors using visual rewards Develop desirable behaviors by working towards tangible goals

*(continued)*

**Table 1.** (continued)

Name of App	Type	Description
TooLoud Too Noisy Kibits Collaboration Show Me	Classroom Apps	Monitor classroom noise level Graphical presentations of the background noise level in a room in an exciting and engaging way Createcollaboration rooms share media Turn your iPad into interactive whiteboard
Mathtopia+ iWriteWords LetterForms	Math and Handwriting Apps	Math game Handwriting exercises
Play Attention SmartBrain Technologies ADHD Kids Trainer KAPEAN Lumosity ACTIVE TARLAN	Cognitive, Executive Functions Applications (games)	Neurofeedback technology that allow you to control the computer by mind/attention alone using tools such as helmets – Improving Student Attention – Enhancing Academic Skills – enhance social skills

Serious games such as Play Attention, KAPEAN, Lumosity, TARLAN, and ACTIVATE have been found effective by researchers [3, 12, 17, 19, 24]. They provide mini games, with attractive animations and sounds, which train different parts of the brain. By experiment, researchers found significant improvements in one or more executive function(s) such as attention, behavioural skills, as well as social skills. In addition, these improvements had a great impact on the academic levels of these children [3, 12, 17, 19, 24].

So, after revising some of the applications and games with their assumed purposes, we selected ACTIVATE to be the instrument to study the interaction effect for ADHD designed applications to improve the cognitive, behavioural and social abilities and skills of ADHD children specifically in Saudi Arabia. We selected ACTIVATE since it is suitable for targeted young children with ADHD. In addition, it targets the eight core cognitive capacities, essentially: Sustained Attention, Working Memory, and Speed of Information Processing. Thus, our focus in this study is to investigate the effect of using technology, particularly e-games such as ACTIVATE, to improve Saudi children with ADHD cognitively, behaviourally and socially. A more detail about the selected instrument will be presented in the next section.

### 3 Methodology

Our goal is to investigate the user interface for e-games that could be used by young children with ADHD at school to increase their attention, processing speed, working memory and control their hyperactivity. The web based instrument was selected to be run on iPad devices by ADHD diagnosed children aged from 6–12 in a classroom settings. Details about measures used, participants, instruments/software specifications, and the experiment method will be discussed in following sections.

### 3.1 Measures

Data was gathered from five sources: Conner's rating scale, teachers and parents interviews, observations and notes taking during the experiment, short talks with the participants after each session and after finishing the experiment, and finally, gathered data by the system itself such as: error rate, duration, scores, etc.

Conner's rating scale was used in this study, by the researcher, to measure the child's behaviour and habits as a preliminary screening for ADHD. Not only does this help to diagnose children who otherwise may have been overlooked, but it also offers a point of comparison for those who do suffer from ADHD [10].

Teachers' and parents' interviews were done at various stages. In the beginning, teachers' interviews helped in selecting the proper participants for our experiment, by pointing those who have some attention or hyperactivity problems within class, (we must mention that severe learning difficulties cases are excluded from this study owing to concentrating on ADHD symptoms only). After that other interviews with same teachers gradually took place to sense any improvements in their behaviour and academic performance during regular classes. Regarding parents' interviews, nearly all of them were done through phone, but we were fortunate to meet some of the mothers at schools. General information was collected, about the student's behaviour, their social skills, whether diagnose with ADHD or not, any medications etc. Later on, couple of interviews were done to see if the student was positively affected by the application, and whether the parents sensed any enhancements in their daughter's life. Feedback from interviews was very supportive and beneficial for this study, it added value to the outcomes.

During testing sessions, the researcher tried not to interact with students unless there were any technical problems or any difficult query from any student, also it was necessary to maintain control in class due to their movements and loud voices. Ethnographical method was used as our quantitative measure, observations and note-taking took place for each participant as a separate case. The researcher documented their conversations during playing with games, their most important reactions and attitudes, problems they faced, the way they helped each other, their hand movements and gestures, and their opinions and judgments about the games. The study analysis included qualitative measures as well. The National Institutes of Health (NIH) have recommended to measure the amount of enhancement in cognitive skills for each student using the NIH toolbox [24]. It was used to gather data about the students' improvements during the experiment. Pre-tests were taken before using the application, and post-tests after finishing the required sessions. Finally, the application generates four individual reports for each participant during the whole experiments. Each presents numerical and statistical data about the level reached, errors done, correct and wrong clicks, time for reaction and the progress of each executive function. These reports were very helpful in analysing and evaluating the interaction. In addition it highlights the points of strengths and weaknesses for each participant, as well as listing some of the effective teaching tips, for each case, to be passed to their teachers.

### 3.2 Participants

The intervention took place in classroom settings by a group of female students aged between 6 and 12 years old. It is important to indicate that the nature of KSA environment separates males from female, due to culture and tradition custom, in some organizations, including educational. Because of that, as a female researcher, the possible and easy choice was to work with female students.

For our case studies, two international schools approved to participate in the experiment. The researcher intentionally selected international schools due to the interface language for ACTIVATE, which is English. A survey was distributed among the parents that contained Conner's scale to assess ADHD. The goal was to initially discover if there were signs for ADHD to those whom are not yet diagnosed, and also to detect if there were actually diagnosed ADHD cases. After detecting students with ADHD symptoms, a consent forms were sent to their parents explaining the application, its assumed benefit, sessions timing and how long the experiment will take. Eventually 17 families signed and agreed for their daughters to participate. So 17 students enrolled, out of 25 who are identified to have signs of ADHD but choose not to participate in the experiment, due to family restrains. For Ethical reasons and anonymity, codes were used instead of their real names. The first school was Al-Hammra international school – English sector, six students participated, one student from the 1st grade (Std 1H), three from 2nd grade (Std 2LB, Std 3K, Std 4LW), one from 3rd grade (Std 5T), and one from the 4th (Std 6M). The second school was Al-Bayan model school – English sector, eleven students participated, one student from the 4th grade (Std 17LH), four from the 5th grade (Std 7JN, Std 8LN, Std 9LS, Std 10JR), and six from the 6th grade (Std 11RG, Std 12I, Std 13RL, Std 14T, Std 15D, Std 16RF). Background information on participants is listed in Table 2.

The ADHD Type for each case was diagnosed depending on the most noticeable symptoms and signs which were observed frequently by teachers and parents, and by using DSM-IV-TR criteria for ADHD [2]. The participants were seated together in a classroom, each with an iPad, with an encouragement to think aloud.

**Table 2.** Background information on participants

Student	Age year	ADHD type	Any medication
Std 1H	6	Inattentive	No
Std 2LB	7	Inattentive	No
Std 3K	7	Inattentive	Yes
Std 4LW	7	Combined	No
Std 5T	8	Inattentive	No
Std 6M	9	Hyperactivity	No
Std 7JN	10	Combined	No

*(continued)*



**Table 2.** (continued)

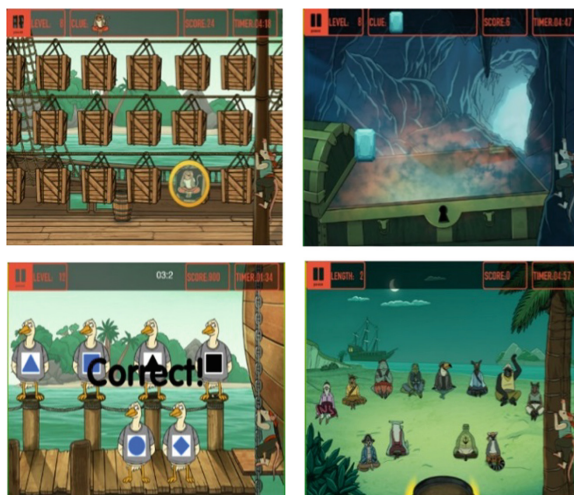
Student	Age year	ADHD type	Any medication
Std 8LN	11	Hyperactivity	No
Std 9LS	10	Hyperactivity	No
Std 10JR	10	Combined	No
Std 11RG	12	Inattentive	No
Std 12I	11	Inattentive	No
Std 13RL	12	Inattentive	No
Std 14T	11	Hyperactivity	No
Std 15D	11	Hyperactivity	No
Std 16RF	12	Combined	No
Std 17LH	9	Combined	No

### 3.3 Instrument Interface Specification

ACTIVATE is a web-based application that provide certain brain-training exercises for children with ADHD to enhance and develop their learning skills in classroom settings. The research presented in [24] identified the executive functions, which is divided into eight core cognitive capacity: Sustained Attention, Working Memory, Speed of Information Processing, Response Inhibition, Cognitive Flexibility, Category Formation, Pattern Formation, and Multiple Simultaneous Attention. These capacities can be strengthen, in children with ADHD, by stimulating them through the system. The application has three portals: teacher, student, and test portals [24].

The educator can manage his students with their accounts through the Teacher Portal. Monitoring their scores in games and progress, their error rate and response speed. In addition, the teacher can compare tests results of each student to measure improvements. Finally, the system generates reports for student which gives details about their strength and weakness, and how much they improved since they begin using the application.

The Student Portal contains six games that target eight cognitive skills necessary for executive functions. The games train the student's ability to move between different tasks, remember sequences, classify items, and reinforce thinking strategies. The games' theme is about being in an island that been discovered by Captain Blue feather and his crew, the student must help them complete levels and collect scores. The Captain introduces each game and gives audio instructions, to help students to understand their tasks. These tasks range from feeding the crew, categorizing items, helping animals and more. Figure 1 represent sample of games offered to students. Each game have hundreds of challenging levels, students are allowed to play each game within five minutes only, four or six games per session according to session timing.



**Fig. 1.** Sample games in ACTIVATE application

In the Test Portal, students undertake three tests pre- and post- the intervention, which are recommended from the National Institutes of Health (NIH), to measure the amount of enhancement in cognitive skills for each student. These tests are done by each participant at the beginning and the end of the training program. The NIH toolbox contains Flanker Task Test, Working Memory Test, and Go/No-Go Test. These kind of assessments can help teachers to measure the amount of cognitive growth in real-time data, and analysis the amount of success, that effected the academic future of students.

### 3.4 Method

In day one, first session, students logged in the test portal and done all three tests to measure their cognitive levels before the intervention. In the next session, they start playing with the games. The target was to complete one thousand minutes of playing, each class must stick to a training schedule of exercise sessions, twenty or thirty minutes per session, from three to five times a week. The schedule was flexible and could be simply modified to meet the demands of any school. The sessions start easy and short to sustain students' enthusiasm, then gradually begin to increase the difficulty level. However, the level of difficulty is set up or down every ten to fifteen seconds to meet the student's abilities based on their error rate, reaction time, and accuracy. Each student pick up an iPad, login their accounts, and start playing one of the six games. The students could play four to six games depending on time provided. The application then automatically terminate the sessions when time is up. There is an animated timer for students to track time. Instant feedback in both wrong and right answers. Colours, sounds, animated objects, all these features were motivating and stimulating the students while playing.

After the intervention, approximately four months later, the students logged in the test portal again to redo the three tests to measure the improvements gained. As

mentioned before, pre- and post- intervention subjects’ scores were collected from teachers to measure enhancement in the academic performance.

## 4 Results and Discussion

Our main objective was to evaluate the effectiveness of game-based technology developed to help ADHD students to overcome their attention, processing problems, and to trigger their cognitive capacities. Follows a discussion of the quantitative results, generated by the system and NIH tests, as well as the qualitative findings from the researcher observations.

### 4.1 Measuring Improvements

Throughout testing, the system generates quantitative data that help in detecting the average of development in cognitive capacities for each student. Table 3 demonstrates each student’s improvement in the eight core cognitive capacities throughout the whole testing period.

**Table 3.** Improvement averages in cognitive capacities of participants

Core cognitive capacities							
Participants	Sustained attention	Response inhibition	Speed of processing	Cognitive flexibility	Working memory	Formation and use	Pattern recognition
Std 1H	7%	30%	33%	0	0	0	31%
Std 2LB	12%	26%	54%	30%	10%	0	0
Std 3K	18%	0	7%	19%	37%	0	33%
Std 4LW	12%	14%	54%	19%	60%	0	0
Std 5T	25%	80%	16%	0	7%	0	0
Std 6M	25%	40%	31%	60%	10%	0	0
Std 7JN	32%	7%	28%	83%	0	0	39%
Std 8LN	35%	64%	80%	42%	0	0	66%
Std 9LS	22%	39%	85%	42%	0	0	66%
Std 10JR	60%	0	70%	42%	7%	50%	66%
Std11RG	70%	47%	39%	29%	7%	0	0
Std 12I	34%	4%	24%	42%	0	0	0
Std 13RL	15%	0	55%	42%	0	64%	20%
Std 14T	9%	29%	68%	22%	0	98%	80%
Std 15D	25%	23%	71%	15%	0	0	88%
Std 16RF	15%	29%	55%	42%	0	0	51%
Std 17LH	25%	0	55%	42%	7%	23%	0

Cognitive capacities marked by zero “0” could not be calculated, as the student did not reach the required level in the games. In fact, all participants got zero “0” in cognitive capacity called “Multiple Simultaneous Attention”, which is eliminated from table, due to unreached required levels; In normal children, we could see how difficult

for them to do multiple things in the same time, so in contrast, it is harder for ADHD children to concentrate on one thing rather than multiple things.

Furthermore, it is obvious, from the results presented in Table 3, that students have improved in the main cognitive capacities such as: sustain attention, processing speed and cognitive flexibility. However, the average of improvement varies between students due to severity of impairments, in addition, it is said to be an improvement even if it was a slightly increase in measurements [24].

By looking at the percentages presented in Table 3, for instance: Std 3K is slow in terms of processing tasks (speed of processing 7%), with lack in focus (sustain attention 18%). Furthermore, when a subject is changed she seems to be stuck in the previous subject (low cognitive flexibility 19%), but on the other hand, she has a very good memory (working memory 37%) and she is good in guessing and figuring things out (pattern recognition 33%).

The least beneficiary from the intervention was (Std 1H), even though she gets the minimum improvement percentages, but her progress was noticeable by her teachers and parents. Other teachers were impressed by her good marks and unusual focusing in the class. Her attention and concentration has improved 7% than before, her speed of processing also improved 33%; she thinks and replies faster now. Also, she enhanced in math by 33% (in pattern recognition).

Another student, (Std 9LS), improved her attention by 22%, she got the highest improvement in processing speed (85%), her teacher acknowledged that she understands better and faster. Her mother noticed that she is more organized in studying than before, and generally in her life, not surprising, her cognitive flexibility has improved 42%.

(Std 10JR) was the perfect model of this experiment, she has transformed from a very hyperactive inattentive student to a better student in all standards. Teacher complained earlier about her uncontrollable behaviour in class, she moves a lot, her low academic level, unorganized, impulsive with her friends, and she does not focus at all. The results showed that after four months of using the brain training games, she is 60% more focus and calm, has enhanced in language and math (formation and use 50%, pattern recognition 66%). she understands and do what she is asked to do immediately (processing speed 70%).

Overall, the improvements in cognitive capacities for all students were remarkable. By calculating the averages, we found that sustain attention has improved by 23%, response inhibition by 28%, speed of processing by 49%, and cognitive flexibility by 38%. The capacities will continue to improve as long as students continue to play. Actually, a lot of parents have asked on behalf of their daughters to continue using the brain training system due to the notable changes they have touched in their children behaviours and skills.

## 4.2 NIH Tests Results

In addition to previous data, other data was generated from tests; students took NIH tests in the first and in the last session to measure their improvement. Accuracy and reaction time were the main parameters in those tests.

In the first test, flanker task, students done very well in the congruent trails. 99% of students select the correct arrow direction with 100% accuracy, with an acceptable reaction time (RT). In the pre-test more than half of the students select the correct direction with an average accuracy 72% and average RT (1645 ms). While in the post test, after intervention, nearly 98% of the students select the correct direction with 100% accuracy, and faster reaction time RT with an average of (1163 ms). The accuracy and RT have been clearly enhanced after intervention. We can say that the average of overall enhancement in the flanker test is by 20%.

In the Go/No Go test, we considered No Go results due to its difficulty to hold back when no action must be done. Before intervention, the average of correct “no goes” was 52%, while after intervention, the average of correct “no goes” was 74%. In the case of Std 1H, we noticed that the score of her pre-test is better than her score in the post test by 5%, which considered normal in ADHD students due to their lack of focusing during the test; despite that, she showed significant progress in response inhibition and processing speed in Table 3, and that is what Go/No Go test measures. The average of overall improvement in this test is 24%.

In the third test, working memory test, the pre-test have shown weakness in the working memory function before intervention, since the average of accuracy was 15%. While the post test scores have shown significant improvements with an average of 27% of accuracy.

After discussing and analysing the quantitative data generated by the system, in Sects. 4.1 and 4.2, and depending on the level of remarkable improvements measured, we can say that the system is effective. This is clearly shown from the positive influence on the behaviour of students as teachers and parents declared, and on their academic level.

## 5 Conclusion

In this study we investigated the interaction of e-games system to measure its effectiveness and whether it could help ADHD children to overcome their impairments, and to improve their cognitive capacities that could affect skills and behaviour. The system consists of six different brain training games, each trigger one or two cognitive capacities. The iPad was used as the tool of the study. Seventeen students were selected, from two international schools in Jeddah city, which have clear signs and symptoms of ADHD. Testing took place in school settings, in-class sessions. Students played three sessions a week, for 20 min for each session. NIH tests were done pre and post intervention, to measure improvements.

The results have shown significant improvements in behaviour and skills quantitatively and qualitatively. Their academic levels have been enhanced and evolved. As evaluation results show, students found the games easy to use and pleasant. Students went through levels in a reasonable reaction time.

So we strongly encourage ADHD children to play with such games, developed specially to enhance their abilities and skills, owing to the probable benefit that may positively change their lives.

**Acknowledgments.** First of all, I would like to thank my two supervisors for their support and guidance. They were there in each step, and helped me whenever I needed them. Secondly, my deepest thanks to Professor Bruce Wexler for allowing me to test ACTIVATE application without any fees, supporting me by sharing his published papers, made a helpful connection to the IT team of C8 Science Company and for being a great consultant too. Also, I would like to thank the ministry of education of Saudi Arabia in Jeddah for giving me the green light to apply a field experiment in different governmental schools. In addition, I Thank Dr. Fatimah Abu Zarifa, Dr. Rafa bin Laden, Faridah Farsi, Elham Ezzy and all school staff members for allowing the experiment to take place in their schools, giving me all the authorities I needed to make this experience succeed. Special thanks to Amal Al-Attas, Maiadah Emarah, Noora Pastukhova to arranging sessions timing and place, they facilitate contacting the parents of the participants as well. Finally, thanks to my parents, husband, friends, and family for all the support I got from them.

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