Empowering Children With ADHD Learning Disabilities With The Kinems Kinect Learning Games

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Abstract: The recent trend in digital games is tightly linked to the natural user interaction technologies that make use of the affordances of sensors like the Microsoft Kinect camera. The Kinect camera detects user's body movements and gestures, which means that the full body becomes the controller. Lately, there is a tremendous interest in developing Kinect educational games. In this paper, we present the innovative Kinems learning games which have been developed for helping children with learning disabilities such as autism, dyspraxia and ADHD improve their skills. The paper contains the outcomes of a recent study, which was to investigate and measure the Kinems learning effectiveness. The research hypotheses were examined through an educational intervention that lasted about one month and was implemented with 11 children with ADHD of 4-8 years old. The study was conducted at the premises of the ADHD unit of the children's university hospital in Athens, Greece. The statistical analysis of pre & post tests showed children' statistical significance improvement of their "Non-verbal intelligence". Furthermore, the results of an in-depth examination of learning and kinetic analysis of children's interaction that showed improvement of their executive functions and cognitive skills. Finally, based on the qualitative comments made by the behavior analysts and researchers, interest and the level children's motivation was high.

Keywords: Attention Deficit Hyperactivity Disorder (ADHD), Kinect games, special education, Kinems.

1. Motivation

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders consisting of three symptom domains: hyperactivity, impulsivity, motor restlessness and attention deficit. Epidemiological studies indicate prevalence rates ranging from 4% to 10% (Cahill et al. 2000). Therapeutic sessions for children with ADHD (Fabiano et al. 2009) aim to help them improve executive functions and specific skills such as:

- *Working Memory*: Children have difficulty in following multi-step directions, trouble with recalling information, and problems in remembering material they read.
- *Flexibility*: Children face problems in transitioning from one activity to another i.e. in stop paying attention to something that is of major interest to them.
- *Time Management*: Children are often unaware of time constraints when executing a task.
- *Motor Planning & Self-control*: Children have difficulties of making a plan before execution, i.e. difficulty in thinking before acting thus actions are often impulsive.
- *Organization*: Children with attentional problems often do not keep track of where they put important items, like completed homework or their team uniforms.

Several scientists have proposed game-based cognitive-behavioral interventions, which seem to be highly promising (Frutos-Pascual et al. 2014). Through gamified structured activities, children can improve memory, concentration, motor planning and time management skills in a stimulating learning environment.

One of the most recent trends in gaming for children with disorders such ADHD is the use of Kinect motion-based touchless games. The Microsoft Kinect sensor is a high resolution (low cost) depth camera, which is able to recognize hand and body gestures. This type of user interaction is by far more natural and appropriate for children with ADHD who need to improve their motor planning and execution skills as well as hand-eye coordination, than the typical input devices for games such as mouse, joystick and keyboard.

However, most of the existing Kinect games, which have been tested on children with ADHD, had not been designed based on therapeutic protocols with the ultimate goal to specifically aim at improving certain skills. Most of them are general purpose exergames such as Braid, Gardens of Time, Kinect Adventures which do not follow specific software/game design guidelines for children with ADHD (McKnight et al., 2011, Bartoli et. al, 2013, 2014, Maliverni et al., 2014, Wang et al., 2014). The most specialized Kinect games for children with learning disabilities are the ones proposed by the Kinems company. Kinems learning games had been designed according to traditional well-accepted therapeutic protocols in order to help children with learning disabilities, including ADHD, to improve their eye-hand coordination, concentration, memory, motor planning and execution skills. Kinems games have already been tested in various authentic learning and therapeutic environments with positive results (see fro example, Altanis et al. 2014).

The goal of this paper is to show the encouraging results from a new pilot research study that aimed to systematically evaluate the effectiveness of the Kinems learning games as a new instructional medium for helping children with ADHD. 11 children with ADHD (4-8 years old) who attend regular sessions the related unit of a children's hospital, participated to this study. This study gave a good insight about the added value that Kinems games can offered to such children. In the following sections, the Kinems design philosophy is being presented followed by the way Kinems games had been evaluated at the children's hospital. The paper ends with some concluding remarks about this study and some future plans.

2. Why Kinems

Fortunately, the blend of cognitive with behavioral interventions (CBI in brief) has been successfully applied to children with ADHD. They aim to facilitate in the management of disruptive behavior, inattention, problem solving skills building, academic performance, etc. (Pontifex et al. 2013). Toplak et al (2008) mention that the rationale and underlying theory for these types of interventions is "the belief that behavioral self-control can be increased by enhancing specific cognitive or metacognitive skills, which are believed to underlie and promote impulsecontrol, goal-directed behavior, or both".

Game-Based CBIs often use structured therapeutic gamified activities that motivate and foster children's concentration in order to meet the specific needs of children. However, most existing CBI games use keyboard, mouse and switches. They focus mainly on behavioral cognitive issues but neglect anything that involves the child's ability to plan and execute motor actions necessary to achieve a cognitive/learning goal (Cassar & Jang 2010). As a result,

therapists have been looking for ways to incorporate embodied interaction practices into CBI game-based learning activities. Researchers assert that gestures and body language not only reveal aspects of learning processes but can also help children learn (Antle et al., 2009). This has also been evident in numerous research studies that had already been published. The most recent ones concern pilot studies around the use of Kinect-based games that involve children with special needs (Karadimitriou & Roussou 2011, Koen de Greef et al. 2013). These games seem to have positive effect on such children despite the fact that they had not been designed with very specific therapeutic goals.

Kinems LLC innovated in this field, since it has been developing specialised embodied learning games using the affordances of the Kinect sensor. At the moment, its gaming suite contains six (6) Kinect games. In close collaboration with special educators and therapists Kinems team had carefully gamified selected therapeutic exercises, which aim to help children improve eye-hand coordination, short-term memory, attention span, sequencing, and problem solving skills. At the moment when this paper was written, the Kinems gaming suite consisted of 5 highly customizable games for Math, Memory, Linguistic and Motor Skills a (available in 3 languages, i.e. Greek, Dutch, and English), which are the following:

- River Crossing: A game for improving visual-kinetic coordination and development of critical thinking
- Mathloons: A game for improving math skills by practicing mental math calculations up to 100
- Farm Walks: A game for improving hand-eye coordination, concentration, and motor planning
- Space Motif: A game for developing spatiotemporal skills and understanding the meaning of sorting, colors, shapes, and the repetition of patterns
- UnBoxIt: A game for improving visual short-term memory and linguistic development

Particularly, according to the Cattell-Horn-Carroll (CHC) Integrated Motel (McGrew, 2009), cognitive abilities that compose human intelligence can be classified in the following 16 broad ability domains: Fluid reasoning (Gf), Comprehension Knowledge (Gc), Short-term memory (Gsm), Visual processing (Gv), Auditory processing (Ga), Long-term storage & retrieval (Glr), Cognitive process speed (Gs), Decision and Reaction Speed (Gt), Reading and writing (Grw), Quantive Knowledge (Gq), General Specific Domain Knowledge (Gkn), Tactile abilities (Gh), Kinesthetic abilities (Gk), Olfactory abilities (Go), Psychomotor abilities (Gp), Psychomotor Speed (Gps). Table I gives an overview of the children's cognitive abilities that each one of the Kinems games tries to promote.

Table1: Cognitive abilities per game

	KINEMS LEARING GAMES				
	River Game	Walks	Space Motif	Unboxit	Mathloons
Fluid Reasoning (Gf)	X				
Short-Term Memory (Gsm)				X	
Visual processing (Gv)	X	X	X	X	X
Auditory Process (Ga)				X	
Cognitive Processing Speed (Gs)			X	X	X
Kinesthetic abilities (Gk)	X	X	X	X	X
Psychomotor Abilities (Gp)	X	X	X	X	X
Psychomotor Speed (Gps)		X	X		

In this paper, we present the quantitative and qualitative results from a research study where five Kinems games had been validated at an authentic therapeutic environment of a children's hospital. Findings from both quantitative and qualitative data will be shown. Also, due to limitation of the paper's length more emphasis will be given on the evaluation of the learning effectiveness of two games, namely the "Mathloons" and the "SpaceMotif". "Mathloons" (see Figure 1) gives children the opportunity to practice all aspects of math, including addition, subtraction, multiplication, and division till the 100s, in a fun and engaging way. Children are called to choose (pump up) the right balloon that represents the correct answer to a math

calculation problem. Appropriate feedback is given for the correct or wrong answers thus resulting in the child's mastery of Math facts. Moreover, through the menu settings, the game can be adapted to the appropriate level of difficulty that a child can cope cognitively. Thus the therapist can change the time limit, the range of numbers (e.g. up to 10, 20, 100, etc.) as well as the operation.

The "Space Motif" game aims at strengthening children's ordering, sorting, pattern matching and spatiotemporal skills. A set of planets and space objects, such as satellites and black holes, appear on the screen (see Figure 2). Children are called to recognized and replicate a given pattern, which consists of objects of the same color, shape or both. They have to pick the appropriate objects and carefully move them around and throw them at a "tube", so that they replicate the given pattern several times. The game can become even more challenging when the therapist changes the settings so that the children are called to create the patterns by moving objects while avoiding collisions with other items or the black hole that appears in their galactic path. And all these exercises could be completed within specific time constraints if the related variable is set. The level of complexity of the patterns (e.g. number of objects) can be adapted to the child's needs from the settings panel.

Finally, a very unique feature of Kinems is that the games are accompanied by a cloud based monitoring and reporting platform where all data from children's interaction are safely stored. It offers clear and constructive information about children's learning achievements and progress, by having all the required information about what has been achieved against expectations in textual and diagrammatic format. It contains both learning and kinetic analytics thus facilitating an in-depth analysis of children's performance over time.

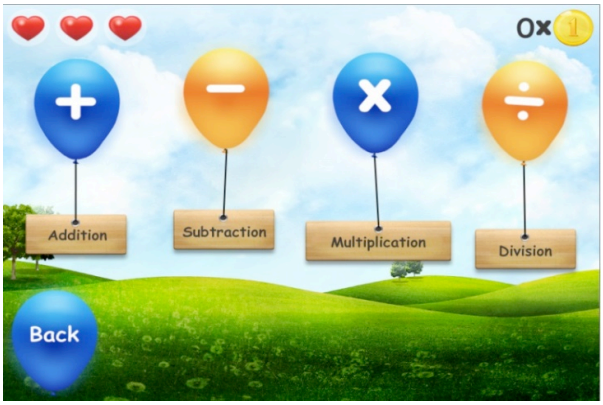

Figure 1. Screen shot of the Kinems Mathloons

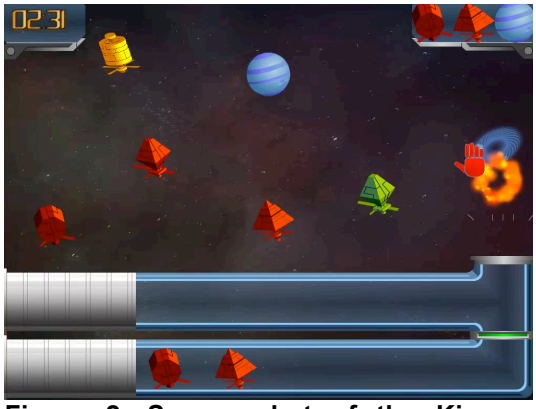

Figure 2. Screen shot of the Kinems Space Motif

3. Research study

3.1 Participants

This study was conducted at the premises of the ADHD unit of the university children's hospital in Athens, Greece. The sample consisted of 11 children (10 boys and 1 girl) who have been diagnosed with ADHD. The average age of the participants was 6,87 yrs ± 1,03 (sd). Their parents had signed consent forms in order for the children to participate in the study. Each child was called to attend 2-3 weekly sessions for one month. The total number of sessions per child ranged from 8 to 11. Each session lasted approximately 30 minutes with no scheduled breaks. There was no use of external tangible means of positive reinforcement. Well-trained psychologists with extensive experience working with children with neurocognitive disorders administered those sessions. Additionally, the order each game displayed at each session was determined by the examiner according to the children's' needs and preferences

3.2 Evaluation hypothesis

The present study aims to examine:

- *If and to what extent the Kinems-based educational intervention is considered effective by contributing to the improvement of the participants' executive functions* (spatial planning, problem solving, sustained visual attention, duration of completion of

problems, concentration and inhibition of impulsivity and working memory) (Hypothesis 1)

- *If and to what extent the Kinems-based educational intervention is considered effective by affecting the acquisition of specialized cognitive goals* (success of completion of mathematical equations in the range up to a 100, recognition and repetition of patterns, motor and visual coordination). (Hypothesis 2)
- *If and to what extent the Kinems-based educational intervention was pleasant and enjoyable* (Hypothesis 3)

3.3 Evaluation Tools

Firstly, in order to be examined if and to what extent the Kinems intervention has an influence on the improvement of the participants' executive functions (H1), pre- and post-assessment test had been utilized, namely:

- the test Tower in order to evaluate the spatial planning and the ability of problem solving. This test is an adapted version of the Tower of London task (Shallice 1982) and is suitable for children aged 6-10 years old. The original widely used test consists of three small rods and three different colored discs. The subject is asked to stack the disks in a way that achieves a specific configuration while moving only one disk at a time, moving the upper disk from one of the rods and sliding it onto another rod or moving a disk on top of the other disks that may already be present on that rod avoiding placing it on top of a smaller disk. The specific test measures problem solving and spatial planning, which consists of evaluating and choosing a sequence of actions that achieve a specific goal. Both are considered important executive functions. The instrument has a Cronbach A of 0,768 .This tool was utilized to measure the number of correct responses in 60 seconds making pre-defined number of movements.
- the Cancellation test, called Wizzards and Dragons, in order to evaluate the sustained visual attention and the duration of completion of problems. This is a classic test, which assesses sustained visual attention by the speed and accuracy with which the child identifies and cancels a stimulus shape among a series of other shapes. Scanning strategy influences speed as well as accuracy. In the present study, this tool was utilized to measure the number of commission and omission errors and the duration of 5 consecutive cancellation tasks, in which the child has to circle a pre-defined number of visual sequences of familiar objects like wizards, dragons, tigers, mermaids, etc. (Papaioannou et al. 2011).
- the Raven Progressive Matrices for assessing the concentration and inhibition of impulsivity (Raven 2000). This is a traditional measure of non-verbal fluid intelligence. It is suitable for children ages 5,5-11 years old. This tool consists of 36 questions classified in different levels of difficulty and its use does not require verbal communication. The subject is presented with a shape that is missing a part and is then asked to identify among six other shapes one that would fit what is missing. A second task requires identifying among six shapes or configuration of shapes the one that is missing from a logical sequence.
- Wechsler Intelligence Scale for Children (WISC III) - Digit span (in Greek) (Georgas, Paraskevopoulos, Bezevengis, Giannitsas 1997): This is a widely used intelligence assessment test that was used to assess the working auditoty memory. In the first part, the child listens to and repeats a sequence of digits said by the examiner. In the second part, the child listens to a sequence of digits and repeats them in reverse order (15 exercises for Digits Forward and Digits Backward).

Furthermore, in order to measure if and to what extent this Kinems intervention affected the acquisition of special cognitive goals (H2), an in-depth examination of the learning and kinetic analytics data, which have been stored at the monitoring cloud platform, was performed. Finally, in order to examined if and to what extent this Kinems intervention was enjoyable (H3), the qualitative comments given by teachers were analyzed.

4. Findings

The 11 children played the Kinems games during 104 sessions that lasted 1.293 minutes. In total 507 reports had been created at the cloud monitoring reporting system. During each session, children played the games that the therapist had chosen according to the child's needs and preferences. Thus, data about the number of times that each one of the Kinems game was played by the children are presented in the table 2 that follows.

Table2. Number of times children played Kinems games

Times of Performance per Game					
	No of children	**Min Times**	**Max Times**	**Mean of Times**	**Std.Dev.**
River Game	11	8	14	10,45	1,75
Walks	11	8	14	9,82	1,78
Space Motif	11	4	13	8,55	3,01
Unboxit	11	4	10	8,55	1,81
Mathloons	11	4	11	8,55	2,25

4.1 Findings concerning the improvement of executive functions (H1)

The first hypothesis of the present study concerned the improvement of the participants' executive functions. The small sample of measurements as well as the lack of a normal distribution required the use of a non-parametric test such as the Wilcoxon Paired Ranks test in order to analyse the differences in children's performance in the aforementioned pre- and post-test for measuring executive functions was examined.

The analysis of the Rave pre & post tests shows that there is statistical significant improvement of concentration and inhibition of impulsivity (p=0,014). Furthermore, almost statistical significant improvement was found for the time completion of the cancelation task 3 that was measured with the sustained visual attention test. This "almost significant improvement" might mean that if the group of participants was larger and the duration of the intervention was longer, this improvement measurement could have been statistically significant.

Moreover, improvement (not statistical significant) at all variables was observed, namely:

- Ability of planning and problem solving (mean change of correct responses=1),
- Duration of problems' completion (cancellation 2 - mean change of time=10, cancellation 3 - mean change of time=18, cancellation 4 - mean change of time=5 and cancellation 5 - mean change of time=1)
- Working memory (mean change of correct responses=1).

These findings are very encouraging especially when the period intervention was short and the number of children was small.

4.2 Findings concerning the improvement in cognitive level

The second hypothesis of the present study examined deals with the acquisition of special cognitive/learning goals. Analysing the data collected via the reporting platform, we identified that children improved their skills. In this paper, emphasis (due to lack of space) is given on explaining how children improved their skills thanks to the “Mathloons” and “SpaceMotif” games.

With regards to the Mathloons games, data about children’s learning performance had been analyzed in order to examine:

- If children improved their performance in solving exercises with mathematical operations over time.
- If children could correctly solve math problems more quickly over time.

Similarly, with regards to the SpaceMotif game, data about children’s learning performance had been analyzed in order to examine:

- If children manage to successfully recognize and repeat patterns.
- If children improve their motor and visual coordination.

The analysis of data of children’s learning paths, that had automatically been stored, shows that all children improved their skills. Indicatively, the learning path of Child11 concerning his success rate in math exercises over time, is presented in Figure 3a,b. The child begins the 1st session playing the game “Mathloons” with the exercises about addition and subtraction (Figure 3a). His performance at the 1st session was 95% while in the 2nd and 3rd session it was excellent. During later sessions, the therapist chose to ask the child to solve exercises with multiplication and division (Figure 3b). Although the child’s performance at the beginning (7th session) was 85%, his performance was constantly improving. As a result, after two extra sessions, his score was excellent.

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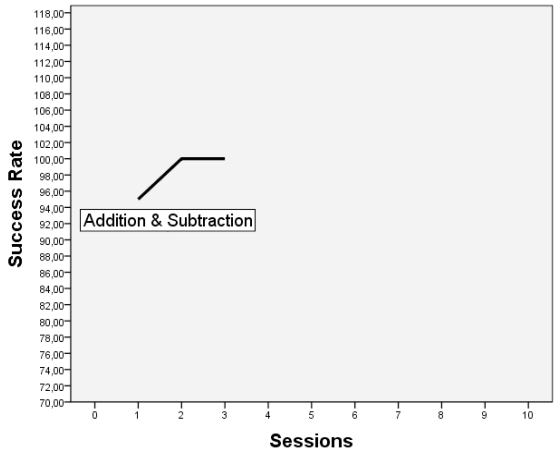

Figure 3a: Learning path of success rate in “Mathloons” (sessions 1, 2, 3)

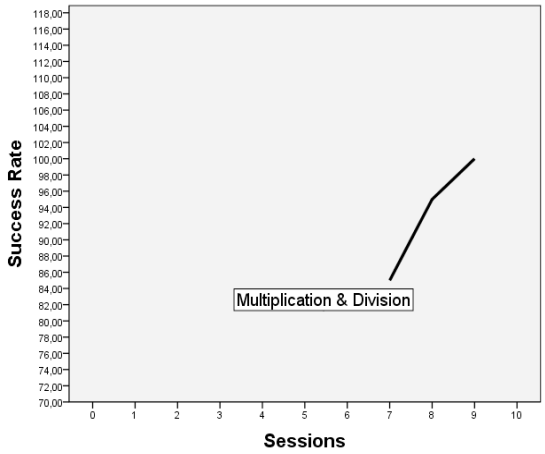

Figure 3b: Learning path of success rate in “Mathloons” (sessions 7, 8, 9)

Similarly, the graphs at Figure 4a,b show the improvement over time with regards to time that took him to solve the exercises during the aforementioned sessions. It is evident that the child manages to correctly solve the exercises in less and less time.

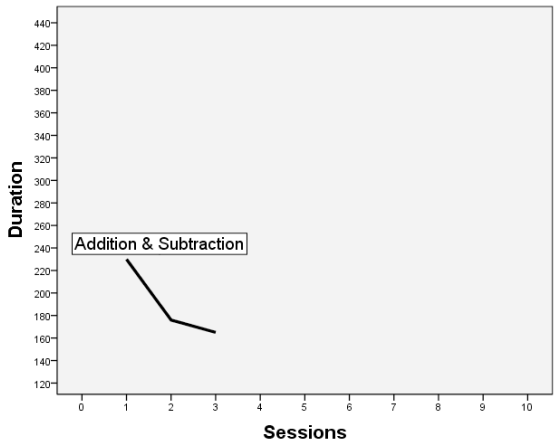

Figure 4a: Time Duration in "Mathloons" (sessions 1, 2, 3)

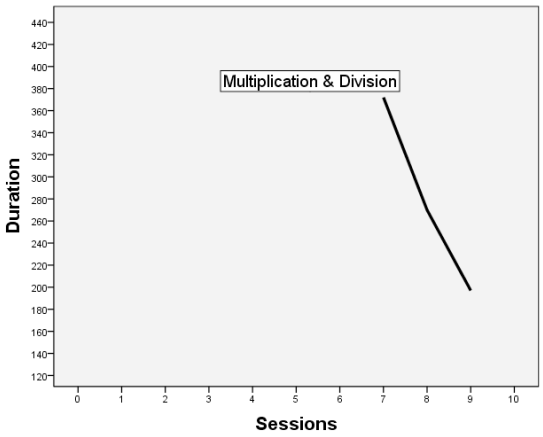

Figure 4b: Time Duration in "Mathloons'' (sessions 7, 8 ,9)

Similarly, the data analysis of all children's learning performance at the SpaceMotif game indicated that the 11 children improved their skills. For example, Child 3 improved her performance in in the recognition of motives as well as her motor and visual after four sessions.

The left graph (Fig 4a) shows that the child initially made two mistakes when she tried to recognize and repeat a pattern of two items. After four sessions, she managed to complete the task with no mistakes.

Respectively, the right graph (Fig4b) concerns the measurement of kinetic and visual skills of the same child during the sessions. The better skills the less crashes when moving items for repeating a given pattern. So, at the first session the child showed some problems with her kinetic and skills visual coordination since she made 40 crashes. Her performance was significantly improved over time thus succeeding in making very few crashes at the 4th session (improvement of 75%).

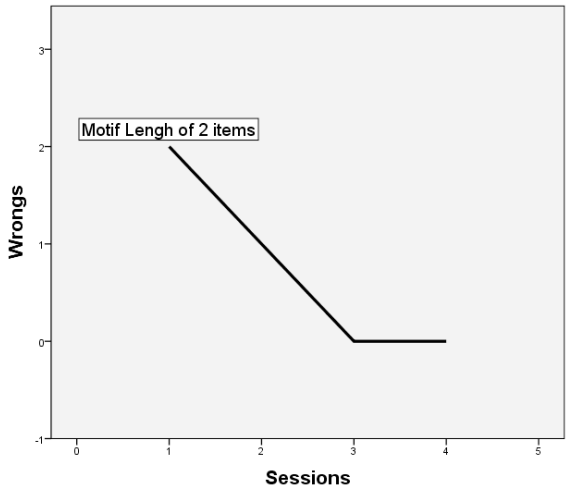

Figure 4a: Learning path at "Space Motif" at the various sessions

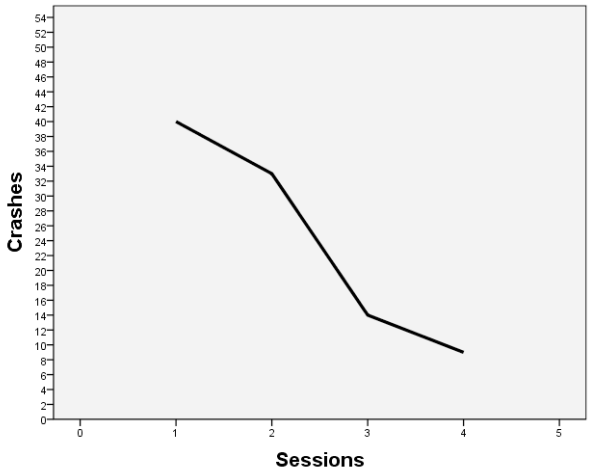

Figure 4b: Motor and visual performance at "Space Motif" at sessions

4.3 Findings concerning the improvement in creation of pleasant environment

Concerning the third hypothesis, according to the therapists' observations, all children showed strong interest and motivation despite their elevated levels of impulsivity and hyperactivity. None of them children gave up. They were quite enthusiastic and frequently displayed signs of disappointment when they had to leave the session despite their fatigue. Also, the level of satisfaction was quite high for the therapists who had very few problems directing the children. The parents made positive comments with regards to the enthusiasm and good mood of the children to participate to these sessions.

5. Discussion

This study strengthens our initial expectations that Kinems approach promotes the acquisition of cognitive skills as well as and the accomplishment of specific behavioral goals of children with ADHD. So, our positive findings concerning the improvement of concentration and attention are in conformity with the results of other studies (see Bartoli et al. 2013, Bartoli et al. 2014, Altanis et al., 2013). Also, children showed strong interest in learning via motion-based games. This is in accordance with the findings of other studies with children with autism, where commercial general purpose Kinect games had been used (see Wang et al. 2014, Maliverni et al 2014).

6. Conclusions

This paper presents the novel idea of integrating Kinect learning games into specialized training programs for children with ADHD. The findings from a research study showed improvement of children's executive functions as well as the accomplishment of specific learning goals. These findings are highly encouraging and enhance the belief that Kinems learning games can add value to the way of helping children with ADHD improve their skills in an engaging way. The embodied interaction modality of these games sustained the interest of a population that is very easily distracted, discouraged or just bored. This study, which is the first of its kind, comes to strengthen the belief that specially designed Kinect games, based on therapeutic protocols, can be proven ideal for children with ADHD since they have difficulties in gross and fine motor skills as well as cognitive skills that need to be improved. Of course, longitudinal studies need to be performed in order to further validate their effectiveness. Future studies, with newer Kinems learning games, are expected to offer new insights to how best help children with disorders.

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