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Children with Motor Impairments Play a Kinect Learning Game: First Findings from a Pilot Case in an Authentic Classroom Environment

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Abstract. This paper presents the first very positive findings from an empirical study about the effectiveness of the use of a Kinect learning game for children with gross motor skills problems and motor impairments. This game follows the principles of a newly presented approach, called Kinems, which advocates that special educators and therapists should use learning games that via embodied touchless interaction – thanks to the Microsoft Kinect camera- children with dyspraxia and other related disorders such as autism, Asperger's Syndrome, and Attention Deficit Disorder, can improve related skills. Several Kinems games have been proposed (http://www.kinems.com). These games are innovative and are played with hand and body gestures. Kinems suggests that games should be highly configurable so that a teacher can modify the settings (e.g. difficult level, time settings, etc.) for the individual needs of each child. Also, a teacher should have access to kinetic and learning analytics of the child's interaction progress and achievements should be safely stored and vividly presented.

Keywords: Learning games, Dyspraxia, Autism, Kinems, Kinect for Windows, Motor Impairments

1 Motivation

Using modern teaching methods combined with the use of specialized assistive technologies can stimulate students with special needs to actively engage in the learning process in order to reach their learning potential [5, 10]. Thus, several learning tools and assistive devices have been proposed to aid children with various disabilities to acquire knowledge and skills.

The most recent technological proposal concerns the natural user interaction technologies like the Microsoft Kinect device, which can detect user movements and gestures and transfer them to the computer. The affordances of the Kinect device are huge. It has opened up new paths in education (http://www.kinecteducation.com/) including special education as well as therapy-rehabilitation [4].

The goal of this paper is to discuss about the use of the Kinect in special education and to present an innovative game for children with dyspraxia and motor impairments, which has been tested in an authentic special school environment. Dyspraxia or developmental coordination disorder, which is the formal and international term, refers to a syndrome that children with various disabilities have when there is a lack of visual-motor coordination due to a non-apparent physical problem ([2][8]). The term dyspraxia comes from the Greek word "praxis", which means "doing" or "action". Dyspraxia affects motor planning and execution – i.e. planning of what to do and how to do it. It is associated with problems of perception, language, and thought [1]. Dyspraxia is a disorder that occurs mostly in children with autism, Asperger's Syndrome, and Attention Deficit Disorder. Several studies have shown that children with dyspraxia often have multiple disabilities, like dyslexia, dyscalculia, or short-term memory problems and they should be treated with individualized educational programs [11].

A major goal for therapists and special educators is to help dyspraxic children in understanding the limits of the human body and help them interact in the physical environment. One of the most innovative approach in the use of technologies for helping children with dyspaxia improve their visual perception, motor planning and execution is the use of motion-based embodied interactive technologies such as Wii, Kinect, Leap Motion. Especially for the Kinect device, the Kinems new approach has appeared. It suggests that the blend of game-based learning and embodied interaction using sensors like the Kinect, can empower children to reach their full potential (http://www.kinems.com). The underlying philosophy of Kinems is that Kinect-based learning games that combine active learning and fun via natural user interaction modalities (hand and body gestures) can improve children's skills despite the fact that they might need to put significant effort [9]. Kinems approach is accompanied by a suite of Kinect learning games that allows a child to interact with the learning gaming environment with hand and body gestures. The innovative features are: i) the teacher or therapist can modify the settings of the game on the fly in order that the game is always adapted to the child's needs; and ii) the data from the interaction (score, mistakes, replay of the interaction movements) are stored in order that the special educator or therapist can see the children's progress as it is depicted with learning and kinetic analytics.

In this paper, the Uni_Paca_Girl game is presented, which accords to the principles of the Kinems innovative Kinect game-based learning approach for children with learning disabilities and multiples disorders. Adapting the basic concept of the well-known "packman" game, the "Uni_Paca_Girl" game was designed so that a child is asked to make horizontal/vertical/diagonal movements by driving a "girl" along related paths (see Figure 1). This game was validated in an authentic special school environment by two children with motor impairments. The findings from the use of the game by two children from a special school of the Attica Region in Greece, who have severe motor impairments, will be presented. The therapists who supported and observed the learning/therapeutic process were highly enthusiastic by the children progress when compared with the students' performance during non-technologically supported therapeutic sessions with the same protocols that this game had gamified.

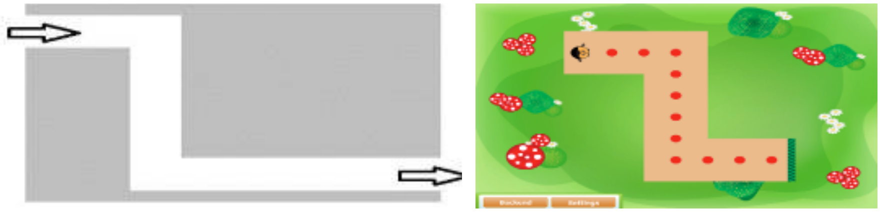

Figure 1. Gamifying the hand movements exercises in the "Uni_Paca_Girl" game

The structure of the paper is as follows: The following section contains a brief literature review on the use of embodied interaction games for the needs of special education. Next, the basic design principles and innovative elements of the Kinems approach are presented. Then, the Uni_Paca_Girl game for children with dyspraxia and motor impairments, which accords to the principles of the Kinems approach, will be described. The final sections concern the way the game was evaluated in a special schools along with the very positive outcomes. By recording and analyzing the children's interactions, it was shown that the game had a positive impact on the children's skills, as well as their motivation for learning and mood. The paper concludes with the way the Uni_Paca_Girl gave ideas to the Kinems team to develop the Walks game, which was also positively evaluated by children with ADHD at a children's hospital. The paper ends with some future plans of the use of such games in special education.

2 Using natural user interaction games for children with dyspraxia and motor impairments

Modern embodied interaction technology (or natural user interaction) is replacing the traditional human-machine interface modalities (mouse, keyboard, touch screens, etc.) [12]. Nevertheless, there is limited empirical research in the field of "motion-based" (or "embodied") touchless interactive games for healthcare and special education, and particularly for children with special needs like dyspraxia and related disorders such as autism [13,14].

Motion based games that use Wii, Kinect and very recently the leap motion sensor have made human-machine gaming interfaces highly popular. Most of these games require active involvement and the exertion of physical force by participants, which are called "exergames", have become very popular. They are designed to provide both fun and exercise for the players. Thus, therapists have started experimenting in cases of rehabilitation and therapeutic sessions for children with special needs.

On the one hand, games such as Konami's Dance Revolution, Happy Action Theater and Microsoft's Kinect Adventures have been used by therapists for rehabilitation programs of people who suffer from motor impairments as well as by researchers who are looking for new effective technologies to help children with dyspraxia, autism and ADHD. One example is the case of the Lakeside Center for Autism in the US that used Kinect's commercial games during therapy sessions for children with autism with ultimate goal to help them overcome difficulties regarding physical and social development [15] Children were very enthousiastic but still the effect was limited. Also a special educator works used the commercial Kinect game "Happy Action Theater" for helping children with autism improve skills that are close to their daily routine [19]. An teacher in Australia used leap motion apps in learning activities that helped children practice their literacy, critical thinking skills, and hand-eye coordination while at the same time enjoying themselves during an immersive learning experience [20].

On the other hand, several studies had been conducted using the Wii or the Wii Fit or the Wii Balance Board, for helping children and adults with both attention problems and gross motor impairments in cases such as: Brain function rehabilitation [23, 24, 25, 26, 27]; Isometric muscle strengthening [28] and Balance training [29, 30, 31] or helping autistic children to develop imitative skills during, rather than after, the streaming video footage [16].

However, there have been a number of studies identifying limited effects of exergaming [7, 24] due to the fact that the embodied interactions integrated into such commercially available exergames were not especially designed for rehabilitation and therapeutic purposes for groups with special needs [12].

Thus, researchers such as Bartoli et al. [13] have reached to the conclusion that more specialized games that address the specific requirements of people with disorders need to be developed. As a result, some studies with prototypes of Kinect learning games have appeared in several publications such as [17, 18, 22]. Casas et al [17] performed a test case five children with autism with a game where children had been virtual puppets that had to move according to specific imitation patterns. Chia et al., [18] proposes a Kinect based for "pet therapy" for helping autistic children improve mainly communication skills. Finally, Chang et al. [22] proposed the use a Kinect based gesture recognition system to help individuals with cognitive impairments to imporve their vocational tasks. In the aforementioned studies as well as others [14, 21], researches highlight the need of performing systematic evaluation studies about the effectiveness of such games.

Perhaps the most mature approach in the special education field is the one proposed by the Kinems team. Kinems (http://www.kinems.com) develops innovative highly configurable Kinect learning games based on traditional therapeutic protocols. Following the Kinems approach, the Uni_Paca_Girl game was developed by gamifying traditional therapeutic exercises for children with motor impairment and dyspraxia.

3 The Kinems Approach

Most computer based learning solutions for children with dyspraxia are rather conventional multimedia drill and practice software tools that can be classified as "closed" software that support the keyboard and mouse as input devices. They do not offer many degrees of freedom in the customization of the learning activities, and do not give much feedback about the children's learning progress, apart from basic descriptive statistics like the number of attempts, a summary of true / false moves, and so on. Software that has as the main interaction device a mouse or a keyboard does not help children in improving gross or fine motor skills and are often inappropriate for children with hyperactivity.

Moreover, special educators and practitioners – i.e. physiotherapists and occupational therapists –follow specific protocols and ask children to perform activities that fit their specific needs. They have to change the difficulty level, use variations of exercises, etc. to keep the motivation of the children high and overpass the difficulties and operational barriers that these children may face during the learning process [6]. For this reason, one should use learning tools that are easily customizable in order that they can be fully exploitable in real practice.

Kinems is a highly innovative learning approach for children dyspraxia that uses embodied interaction technologies. Kinems offers a Kinect learning gaming suite for helping children with dyspraxia, autism, ADHD and motor difficulties to improve their eye-hand coordination, visual perception, motor planning and execution skills and simultaneously cultivate mental capabilities, reach planned levels of school performance according to the indicators of their cognitive abilities, and gain experiences through interactive learning games.

The pedagogical framework of the Kinems approach is that the multi-sensory games follow the four principles of therapeutic - educational intervention of Cain and Seeman [3]:

- Repetitive exercises
- Personalized flow of learning activities
- Combination of visual, auditory, and kinesiology stimuli
- Step-wise activities with frequent feedback and reinforcement

The key technological innovation is the use of the Microsoft Kinect for Windows device. This highly accurate depth camera detects all the movements of the body, making the human body itself a remote control that facilitates the human computer interaction. Thus, children interact with the educational games in a simple and natural way, making only simple hand movements and body gestures. For example, if requested by a child to do certain coordinated moves (e.g. horizontal moves from left to right) he or she can choose objects within a Kinems game (i.e. a boat) to move from one point (i.e. an island) to another point (i.e. another island) following a path (a river or bridge). The child will do it with hand movements as required according to the therapeutic protocol and not with the aid of a mouse.

The second technological innovation is that the children's interaction, performance and movements during the therapeutic game play are recorded in detail and are stored on a cloud server. Thus, the teacher/therapist can see a "playback" of the movements of the child and her performance in the game anytime, anywhere, and with any device. Therefore, reports can be produced that could be shown to the parents and other stakeholders when necessary. Kinems now offers a suite of six (6) learning games that help children K-9 improve motor planning, visual kinetic coordination, visual and audio short-term memory, math skills, concentration, and linguistic development. Special educators and therapists, via the back-end monitoring and reporting system, can easily customize the games on the individual needs of a child by selecting the settings, such as the appropriate difficulty level or the type of the activity. The basic set up for the Kinems games requires the Kinect for Windows camera attached to a laptop or desktop, which can be connected to a TV screen or projector or even to an interactive whiteboard (see Fig. 1).

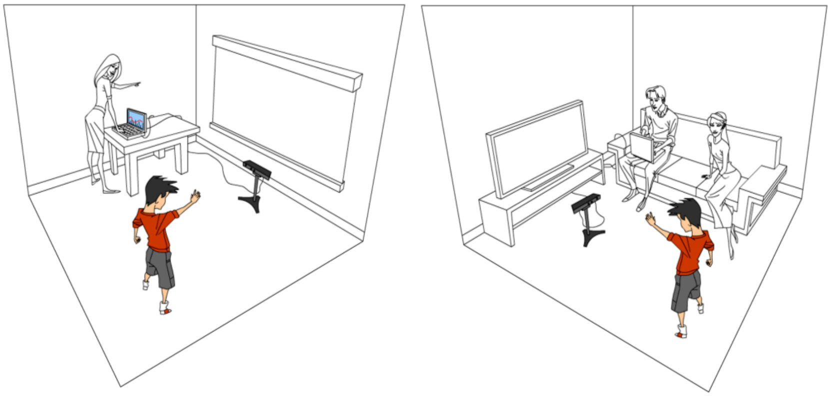

Figure 2. Set up for playing the Kinems learning games

The Kinect camera captures three-dimensional data, as it has a depth sensor, which with the help of an infrared projector and RGB camera, creates a digital image of the user's body. Thus, any movement made by the user can easily be detected and be recorded.

4 The Uni_Paca_Girl game in a Special School: A Case Study

4.1 Overview of the "Uni_Paca_Girl" game

The "Uni_Paca_Girl" game was designed to help a child (with the support of a special educator) build and develop basic gross motor planning and co-ordination skills (back, front, top, bottom, right, left, etc.) in a playful and entertaining way. As Kinems approach suggests, the core idea of this game is to transform basic therapeutic exercises of hand movement in front of a mirror for improving children's gross motor skills. Discussing with therapists, it was found out that children do not complete such exercises due to fatigue and boredom. So when they feel that an exercise is difficult for them, they quit since there is no motivation to complete the task. Thus, a main goal of this game is make children with motor impairments highly engaged in playing a simple game so that they will overpass their fatigue or difficulties in hand movements.

The Uni_Paca_Girl game is an adaptation of the well-known “packman” game. In this game, a child is asked to control with his/her hand a little girl and move it along horizontal/vertical/diagonal paths and other paths like mazes. While walking carefully along the paths “red dots” are being collected (see Fig. 2).
The *Uni_Paca_Girl* must move carefully along the path in order to avoid coalitions at the edges. While moving, she is collecting “red dots”. There are several settings in the game such as:

- Type of path, i.e. horizontal, vertical, or diagonal paths
- Time limit
- Width of the path
- Length of the path, 20-40-60 cm

The therapist can choose among different types of paths (such as horizontal, vertical, or diagonal paths) and specify time limit. Also, depending on the capabilities of the child, the difficulty level of the game in the sense of the width of the path can be modified thus making the game more or less challenging (see Fig. 3).

Figure 3. Settings of the “Uni_Paca_Girl” game

This game invites children to combine simultaneously many skills, such as their attention, their ability to coordinate properly their movements in space, and react quickly when needed. At the end of each game, the players have the opportunity to check their mistakes and try to do better, thereby improving these skills gradually.

At the end of each game, teachers and children have the opportunity to check their mistakes and try to do better, thereby making plans on how to proceed with other therapeutic sessions for improving children’s gross motor skills and attention-concentration gradually. Thus, the game is accompanied by a back-end monitoring system where data about the child’s achievements and progress are shown. Thus, during the game interaction, the game engine captures the hand movements in order to visualize them appropriately. Thus, when the gamified training session is over, the teacher has access to a screen (see Fig 4), which shows visually all the attempts that the child made and the time spent in the game. There is also the possibility to “replay” the mode of interaction in the game and all the movements of children along the various paths (like a video replay of the child's movements).

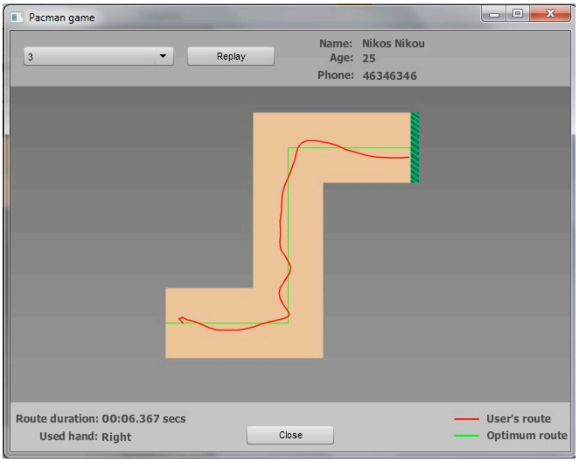

Figure 4. Reporting system of the "Uni_Paca_Girl" game

4.2 Evaluation Method

Two students in a Greek special school who are facing motor impairments agreed to play the Uni_Paca_Girl game under the supervision of a special educator. The first student has severe left hemiplegia, which originated from postoperative ischemic stroke. He has high perception and good IQ. The second student has cerebral palsy with quadriplegia and moderate IQ.

The experiment was divided into two phases. During the first phase, students were asked to perform in a typical manner the basic movements that they normally do during the therapeutic sessions. During the second phase, the students used the Uni_Paca_Girl game to perform the same movements. They were called to perform horizontal, vertical, and diagonal movements/paths as well as some complex paths that looked like a labyrinth by moving with their hand a "girl".

For the needs of this experiment, the time and the number of attempts for doing a hand movement along a path were calculated. The instability of the students' hands was examined by measuring how many times a student drove the "girl" to the edges of the path.

4.3 Evaluation Findings

Table 1 and Table 2 show the students' performance when doing horizontal movements with the "typical" procedure and when playing the educational game.

Table 1. The performance of the 1st student in the exercises in a natural way as well as within the Kinems game-based learning environment

1st student		
Hand	**Time in a natural way / Efforts Made**	**Time with Uni_Paca_Girl game / Efforts made**
Horizontally from left to right 20 cm		
LEFT	6’’ / 1 efforts	5’’ / 1 effort
Horizontally from left to right 40 cm		
LEFT	10’’ / 2 efforts	7’’ / 1 effort
Horizontally from left to right 60 cm		
LEFT	15’’ / 2 efforts	13’’ / 1 effort
Horizontally from right to left 20 cm		
LEFT	8’’ / 1 efforts	3’’ / 1 effort
Horizontally from right to left 40 cm		
LEFT	13’’ / 2 efforts	4’’ / 1 effort
Horizontally from right to left 60 cm		
LEFT	18’’ / 3 efforts	15’’ / 1 effort

As shown in Table 1, the improvements in time and number of attempts for the 1st student were quite significant. On average, the improvement in time for doing a movement for the 1st student was 34, or 73% in favor of the Uni_Pac_Girl game. The improvement in the number of attempts for doing the hand movement in the right way was 36, or 11% in favor of the Uni_Pac_Girl game.

Table 2. The performance of the 2nd student in the exercises in a natural way as well as within the Kinems game-based learning environment

2nd student		
Hand	**Time in a natural way / Efforts Made**	**Time with Uni_Paca_Girl game / orts made**
Horizontally from left to right 20 cm		
RIGHT	9’’ / 3 efforts	8’’/ 1 effort
LEFT	11’’ / 2 efforts	7’’/ 1 effort
Horizontally from left to right 40 cm		
RIGHT	15’’ / 4 efforts	11’’/ 1 effort
LEFT	20’’ / 4 efforts	23’’/ 2 efforts

2nd student		
Hand	**Time in a natural way / Efforts Made**	**Time with Uni_Paca_Girl game / orts made**
Horizontally from left to right 60 cm		
RIGHT	25’’ / 4 efforts	34’’/ 1 effort
LEFT	34’’ / 5 efforts	26’’/ 1 effort
Horizontally from right to left 20 cm		
RIGHT	10’’ / 2 efforts	8’’/ 1 effort
LEFT	9’’ / 3 efforts	14’’/ 1 effort
Horizontally from right to left 40 cm		
RIGHT	18’’ / 3 efforts	27’’/ 1 effort
LEFT	20’’ / 4 efforts	50’’/ 1 effort
Horizontally from right to left 60 cm		
RIGHT	27’’ / 4 efforts	31’’/ 2 efforts
LEFT	30’’ / 4 efforts	33’’/ 1 effort

As can be seen from Table 2, the second student also managed to perform the hand movements with fewer attempts. On average, the improvement in the number of attempts for doing the hand movement in the right way was 59, or 44% in favor of the Uni_Paca_Girl game.

Similar analysis has been done for all the various exercises that the children were called to perform, both in a “natural” way and in the Uni_Paca_Girl game. It was found that for the 1st student, the average improvement in the time of completion to a path was 44, or 18%, and he required 41, or 10% fewer attempts to make the proper movement in an accurate way. Respectively, the improvements for the 2nd student were 2, or 05%, and 67, or 08%. The 2nd student faced more severe motor impairments and his intelligence level was moderate, which hindered him in immersing into the gaming environment as easily as the 1st student did.

The analysis of the data gathered showed that the Uni_Paca_Girl game helped significantly both children in the realization of the therapeutic exercises. They managed to perform the exercises within the Uni_Paca_Girl games with much less effort than the effort spent doing the same exercises in a typical therapeutic way. Actually, the children were highly engaged in playing the game that they over passed their fatigue or difficulties in physical movements. In addition, it was found that the first student made the movements faster within the Uni_Paca_Girl game than in a typical way. The game helped the student make faster movements. For the second child, the duration for performing a hand movement was more or less balanced.

From the interviews taken from the two therapists, the following positive comments were made about the Uni_Paca_Girl game:

- Children were highly motivated and engaged while playing the Uni_Paca_Girl game, even when the activities demanded great physical effort.
- Students carried out the exercises of the Uni_Paca_Girl game very pleasantly and wanted to continue playing despite the fatigue that appeared after several attempts.
- Kinect game can contribute to the synchronization of the hand's physical movement with the eye's visual perception and focus.
- Using the Uni_Paca_Girl game, a child has a very good mood, performs the exercises in a very calm way, thus keeping his or her muscles relaxed, which can lead to very positive effects when trying to improve motor skills.
- Through the Kinect game a disabled child can perform movements that have not been tried in a typical way (such as a longer or a more complex path), as the child is carried away and wants to complete it by trying harder until the end. On the contrary, during traditional physical movement, the child can unconsciously stop the effort by not believing he or she can accomplish it.
- It is easier for the therapist to have an analytical view of the child's progress at a specific session or for a period of therapeutic sessions. Furthermore, the progress reports are more convenient and handy to use. The video-reply shows the child's movements in great precision and offers an objective assessment of the child's progress. Thus, the therapist knows exactly the way the movement was performed by the student.
- The whole movement of the child can be repeated through function replay anytime, thus the way the movement was made is visible extensively and analytically anytime by the therapist. With the natural way, the performed movement cannot be repeated and therefore, it should be recorded the next time it occurs.

It is important to note that both students really enjoyed carrying out the therapeutic exercises in the Kinect-based gaming environment. Normally, in a "typical" therapeutic session after 3-4 attempts with hand movements, children get tired and want to take a break. With the Uni_Paca_Girl game, no break was asked to take place.

5 Concluding Remarks

The outcomes from the evaluation of the Uni_Paca_Girl game were highly promising. They are in accordance with the findings of other researches, e.g. [22]. The positive feedback from this game made the Kinems team to build a game called "*Walks*". In the "*Walks*", the child controls a farmer who tries to gather the harvest carrots within a short time. There are obstacles such as the snakes aiming to make children more focused and control better their hand movements.

Figure 5. Screenshot of the Kinems Walks game

The Walks was one of the games that 11 children diagnosed with ADHD (10 boys and 1 girl) played for 11 therapeutic sessions of 30 minutes. One (1) child was also diagnosed with Autistic Spectrum Disorders (ASD). The experiment happened at the specialized ADHD unit of the children's hospital Aglaia Kyriakou. Overall, the training sessions were completed with success. All children showed strong interest and motivation despite their inherent elevated levels of impulsivity and hyperactivity. Although, it is outside of the scope of this paper to describe the findings of that evaluation case study, the level of satisfaction was quite high for parents and the trainers faced very few problems in guiding and supporting the children.

From the findings of both cases, it was evident that in an immersive embodied environment, which offers playful learning experiences, a child has an active role in utilizing senses and imagination. Experts agree that learning games are very attractive and effective media that promote children's acquisition of knowledge and skills. Kinect learning games using the Kinems approach seems to help special needs educators meet the demands of 21st century education:

- Simulate engaging learning assessments
- Assist with students' physical and emotional health
- Offer pluralistic personalized learning experiences within a learning session
- Increase academic rigor

The combination of the motion-sensing technology of the Kinect device with learning gaming aspect, makes this approach highly innovative and highly promising for helping children with learning needs improve their skills. Additionally, the special educator can monitor the child's performance and produce reports based on detailed data of the child's interaction in the gaming environment. New games based on therapeutic protocols and new evaluation case studies need to be made before drawing firm conclusions about the effectiveness of such games.

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