



Original Article

## Using health games for rehabilitation of patients with infantile cerebral palsy

WAN-CHEN LEE, MSc<sup>1)</sup>, MIRIAM C. REYES-FERNÁNDEZ, BSc<sup>1)</sup>, RUBÉN POSADA-GÓMEZ, PhD<sup>1)\*</sup>, ULISES JUÁREZ-MARTÍNEZ, PhD<sup>1)</sup>, ALBINO MARTÍNEZ-SIBAJA, PhD<sup>1)</sup>, GINER ALOR-HERNÁNDEZ, PhD<sup>1)</sup>

<sup>1)</sup> *Research Division and Postgraduate Studies, Instituto Tecnológico de Orizaba: Av. Instituto Tecnológico 852, Col. Emiliano Zapata, Orizaba 94300, México*

**Abstract.** [Purpose] The purposes of this study were to evaluate whether the therapeutic games developed by the study team are significantly effective for upper limb rehabilitation of patients with cerebral palsy and to assess the development of the games and the evolution of patients throughout the therapy sessions. [Subjects and Methods] This study demonstrates the results of using therapeutic games in patients with infantile cerebral palsy. The therapies were performed in 30-minute sessions for about 1 to 4 months. This study shows the progress of five children with cerebral palsy during the sessions. The time it took the children on each road and the times required to complete a task were measured. In addition, the level of difficulty of the games was gradually increased at each session. [Results] Results have shown good progress on the accuracy of the movements and an increase in concentration level during the execution of the games, showing an improvement in the patients' performance by 40–55% faster. [Conclusions] Health games encourage children to comply with therapy. The advantage of the game is that the patient can perform the therapy at home, which could help achieve further progress in patients.

**Key words:** Infantile cerebral palsy, Rehabilitation games, Computer games

*(This article was submitted Feb. 18, 2016, and was accepted May 14, 2016)*

### INTRODUCTION

Cerebral palsy (CP) is a no progressive disorder of the immature brain that results in movement and postural control impairments. CP is the most common cause of physical disability in childhood<sup>1)</sup>. The syndrome of CP encompasses a large group of childhood movement and postural disorders. The incidence of CP, a lifelong disorder is 2–3.5 cases per 1,000 live births<sup>2, 3)</sup> and has remained stable in the past 40 years. Therefore, studies and research on children with CP are important for the improvement of patients' disabilities.

Weightman et al.<sup>4)</sup> showed that the use of computer games is good and provides a positive result for the recovery of muscle movements in children with CP. To help improve the movement of the upper limbs of children with CP, therapeutic games have been designed, especially for upper limb rehabilitation.

In recent years, the importance of using technology to help improve therapies and patient assessments has become accepted in rehabilitation. Human integration of a computer or robot has also been used in the medical field for rehabilitation<sup>5, 6)</sup>. The use of video games to help patients with their rehabilitation therapy has shown positive results<sup>7)</sup>, particularly the use of *Nintendo Wii*<sup>®</sup> games in rehabilitation<sup>5, 8–10)</sup>.

Videogame therapy has also been used in elderly patients, resulting in a significant improvement in balance and mobility in these patients in comparison with other participants who received traditional therapy in a conventional treatment room<sup>8, 11)</sup>. Li et al.<sup>12)</sup> showed that the video game exercise could engage participants' attention for a longer period than traditional and tracking exercises. Keith et al.<sup>13)</sup> showed that integrating game into therapy can increase the time spent by patients in therapy. In addition, they suggest that through detailed research and development, video games might be a safe, cost-efficient, and

\*Corresponding author. Rubén Posada-Gómez (E-mail: pgruben@yahoo.com)

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effective supplement to conventional physical therapy. After using *Nintendo Wii*<sup>®</sup> games in rehabilitation, 75% of patients indicated subjectively that it seemed as useful as, or even better, than conventional rehabilitation, 81.3% found it fairly enjoyable, 87.5% wanted to continue using it as part of their rehabilitation program, and 93.8% were willing to recommend it to other patients<sup>5</sup>).

King et al. showed that the use of interactive platforms is more attractive for patients than performing tedious and repetitive exercises<sup>14</sup>). In addition, this kind of platforms allows patients to perform their exercises at home<sup>7, 9, 16, 17</sup>); thereby, patients are able to increase their therapy time. The additional tools used in rehabilitations, such as computer programs, are easy to install and physically simple, light, and small. For all these advantages, the computer is a powerful support tool in rehabilitation. Likewise, the augmented reality has proved more effective than conventional treatments<sup>18</sup>). However, neurorehabilitation usability studies have found that off-the-shelf games may actually provide negative additive and visual feedback because patients are not fast enough or efficient enough to perform the movements required to play the game successfully<sup>7</sup>).

Shah et al.<sup>19</sup>) reported that rehabilitation games need to be designed specifically for the purpose of rehabilitation and be customizable according to individual needs. Several studies have shown the benefits of using games developed specifically for rehabilitation purposes<sup>19, 20</sup>).

Hence, games specifically for rehabilitation of the upper limbs were developed, focusing on application in children with CP, in order to achieve adequate support for patients. This project allows interaction with the physician, in which the physician can design the path of the game when a specific movement of the patient is required. A great advantage of this rehabilitation game is that it can be customized to suit the specific needs of individual patients.

## SUBJECTS AND METHODS

In order to use this therapeutic game that the study team developed, a regular computer should be connected to a large screen, TV, or projector. A webcam or camera (*EyeCamera PlayStation 3*<sup>®</sup>) should be connected to the same computer to video-record the whole process during the game. Patients use a red, blue, or green LED pencil to install and manipulate the game (Fig. 1).

The reason for using a projector in the case study was that the size of the image was adjustable; therefore, adjustment could be made depending on the range of motion of the patient's arms. The LED pencil could be turned on in two ways as follows: switch to the top or button, or retain in the middle. Each patient's ability to move the fingers was considered. Another prototype bracelet LED was also made for the patients who could not hold a LED pencil. The LED was placed inside a small sphere of glass and filled with hot melt. When the pencil was switched on, the LED light was focused in different directions (Fig. 1). As LED is unidirectional, light is focused on the top. If the top LED switch is turned on in another direction, the light that seen on the camera will be markedly decreased or even disappears.

Two sets of rehabilitation games were developed to stimulate the upper limb, in which patients were required to perform flexion, extension, pronation, and supination of the arm movements and hand grip, which are the fine motor skills of the arms and hands. The rehabilitation game was designed with different levels of difficulty that can be played depending on the outcome in patients. There by, patients are encouraged to improve their fine mobility.

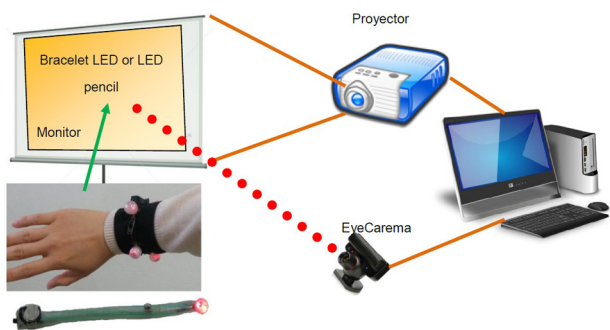
In order to perform this therapeutic game, before the game starts, the patient needs to hold the LED pen and point it to the car movement on the screen during the game. When the game starts, the patient moves the LED pen and follows the road to the final destination. The patient should maintain the car inside the road. When the patient pushes the car on the screen off the road, an error will be recorded. At the end of each level, information such as playing time, number of errors, and the patient's evolution will be recorded (Figs. 2 and 3).

The objective of the game is to stimulate patients to move their arms in straight, curved, circle, square, rectangle, spiral, and triangle lines, among other movements. At the most-advanced level, the roads are more complex and the widths of the roads are narrower (Table 1 and Fig.4). The more the patients can focus and perform more-complex and more-precise movements, the better are the results obtained.

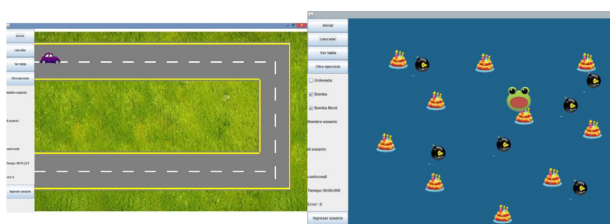
The second game is called frog eating pastry. This game has a similar purpose to the previous one. It consists of a frog eating pastry while avoiding touching moving bombs (Fig. 2). In this game, the movements are not limited in order to capture all the pastry and finish the game. During the game, the patients have to move their arms in straight, curved, and rectangular lines, among other types of movement, but with more freedom and faster. This game focuses on agility of arm movements. The patients can exercise their thumbs while pressing the button at the same time.

The previous two games, besides being useful for exercising the arms, are also useful for children to identify colors and images, and differentiate functions. The differentiation is done by accounting and identifying the different sounds and their meanings as presented in the games. When the patient goes to wrong way, a beeping sound would signal for the error. When the game ends, an applause sound is made. When the patient fails to point the car to the correct direction, a sound will signal the patient to correct the error.

All the experiments were completed in accordance with the Ethical Principles for Medical Research Involving Human Subjects of the Declaration of Helsinki developed by the World Medical Association<sup>20</sup>). Thereby, the risks for the participants in the performance of the tests were minimized as much as possible. In addition, this study was reviewed by the institutional board. All the participants were informed about the procedures of the test, and their written consent were obtained before the study.



**Fig. 1.** Description map of installation using LED pencil or bracelet LED



**Fig. 2.** Car game and frog game



**Fig. 3.** Patient performed the game

a		b		c		d		e	
f		g		h		i		j	
k		l		m					

**Fig. 4.** Shaped road

**Table 1.** Road game

Level	Road width (cm)	Road length (cm)	Shaped road
Level 1	20	285	Fig. 4-a
Level 1A	20	230	Fig. 4-b
Level 2	21	190	Fig. 4-c
Level 3	16	490	Fig. 4-d
Level 4	16	390	Fig. 4-e
Level 4 A	15	400	Fig. 4-f
Level 5 A	11	660	Fig. 4-g
Level 5 B	11	430	Fig. 4-h
Level 6 A	7	450	Fig. 4-i
Level 6 B	7	500	Fig. 4-j
Level 6 C	7	550	Fig. 4-k
Level 7 A	7	530	Fig. 4-l
Level 7 B	7	600	Fig. 4-m

## RESULTS

In order to achieve the purpose of this study, children with CP aged between 6 and 12 years who had some difficulty of the upper limbs and hand movement but still able to perform the game were selected. This study was conducted with five children with CP whose ages ranged from 6 to 10 years. The duration of playing the game for its therapeutic purpose is between 30 and 135 days. Table 2 presents the data of the patients at baseline and after performing the game therapy.

The progress of the patients in this study was based on the level of the games and errors they made. The error refers to the number of times the patients deviated from the road between the first and last weeks. The duration of the exercise represents the degree of active movement of the arms and forearms. The number of times the patients went off the road indicates limitations of active movement, flexion and extension of the fingers, wrists, and forearms.

Table 3 presents the results of the average racing game that were played by patients for 16 weeks. It shows the average time in seconds and the number of times the patients got off a defined road in the first 2 weeks and last 2 weeks.

According to the results presented in Table 3, a makeable progress occurred between  $T_0$  and  $T_1$ ; the results demonstrated an error reduction rate from 40% to 55%. The patients had improved their active movement, and flexion and extension of arms and forearms. At the beginning of the game, the patients found it difficult to raise and extend their arms. When they started exercising, their arms got tired easily. After several months, the patients were able to extend their arms a little more and did not get tired easily. Table 3 also shows improvement in terms of correctly drawing the car within the defined road. In the basic road, the speed was reduced by 49%. However, the number of times the direction deviated from the road was not reduced. The standard deviation of the number times the direction deviated from the road in the basic level was 38.34. It is because some patients wanted to achieve their target levels eagerly and did not pay much attention about how well they were able to finish the game.

In the medium level of the game, results show a 55% increase in speed and 49% correct movements inside the road. The numbers demonstrate significant improvement in flexion and extension of the hands, wrist, and fingers. After the therapeutic

**Table 2.** Data of the patients

	P1	P2	P3	P4	P5
Age (yrs)	10	9	8	6	7
Hand to exercise	Left	Right	Left	Right	Right
Height (m)	1.45	1.40	1.35	1.20	1.30
Weight (kg)	38	40	30	32	35
Espasticity	Left hand and left foot	Feet, back, arms, and hands	Feet, back, arms, and hands	Hands and feet	Hands and feet
Exercise time (months)	4.5	1.5	2	1	2
Session duration (min)	30	30	30	30	30
Position	Stand	Sit	Sit	Stand	Stand
Hand commonly used	Right	Right	Left	Right	Right
Initial description	Can walk, write with the right hand, but weak left hand	Cannot stand up, cannot straighten the back, cannot take with both hands, and have difficulty speaking	Cannot stand up, cannot straighten the back, cannot take with both hands, and have difficulty speaking	Does not have good hand movement	Does not have good hand movement
GMFCS level	I	IV	IV	II	II

**Table 3.** Results of the average racing game

	T0	T1	%reduced time	SD*
Speed taken to finish a basic-level game (levels 1–4), s	41	24.4	40%	11
Speed taken to finish a medium-level game (level 4A–5B), s	78	35.2	55%	7.1
Speed taken to finish an advanced-level game (levels 6 or 7), * s	63.1	34	46%	----
Number of times the patients got off a defined road: width, 20–16 cm (levels 1–4)	5.24	5.26	–6%	38.34
Number of times the patients got off a defined road: width, 15–11 cm (levels 4A–5B)	18.7	9.5	49%	14.27
Number of times the patients got off a defined road: width, 7 cm (level 6 or 7)*	14.3	8.46	41%	----

\*Level achieved only by patient 1 (P1), T0: Average result of the first 2 weeks, T1: Average result of the last 2 weeks, SD: Standard deviation of the percentage of time reduction for all the patients

games, the patients could hold the marker better, displaying better agility of the finger to press the button to start the game and better wrist movements. These improvements were caused by the reduction in the number of times the direction deviated from the road. However, at the advanced level, only one patient (P1) achieved the goal. The game is designed to allow the patient to enter the next level after completing the previous levels.

The standard deviation of the increases in speed of the five patients was 11 and 7.1. The results showed a similar increase in speed among the patients. However, among those patients, patient 1 participated the longest time (4.5 months) in the study. He also had better study results, 63.7% increase in speed in the medium level, and an average of 74% reduction in the number of times he deviated from a defined road.

Even though the therapeutic duration of each patient varied, the improvement of each patient was noticeable. The patients who participated in the game longer showed significant improvements, including the reduction in the time to finish the game, better movement inside the defined road, and better ability to hold the marker.

At the end of the therapies, the participants were interviewed for their impression about the games. Several questions were asked, such as the following: “Do you like this therapeutic game?” “Do you find the games interesting to use?” “Would you like to continue performing this game?” The survey results show that the participants felt interested to use the rehabilitation games, and the duration of the therapies was increased. The participants paid more attention to the therapy and enjoyed the games.

Table 4 shows the comparison of the activities and movement of the patients between the baseline and after the game rehabilitation therapy.

**Table 4.** Comparison between before and after the experiment

	Before the experiment	After the experiment
P1	Left hand, wrist, and fingers weak	Left hand had enough strength to catch a ball and turn a key to open the door, among other fine motor exercises
P2	Could not take with both hands	Could paste paper inside a shape and draw a straight line on paper, could hold the pencil harder, could paint hard and inside a picture frame, and could cut sheets of paper straighter than before
P3	Could not hold well the marker and had trouble moving the arm and point maker inside the game route	Could hold the marker better and had better arm movement
P4	Could not hold well the marker and had trouble with wrist movement	Had better arm and wrist movements
P5	Could not hold well the marker and had trouble moving the arm and point maker inside the game route	Could hold the marker better and had better arm movement

## DISCUSSION

The study results from the five patients provide a breakthrough in the movement abilities of the arms and hands of the patient. These results show that rehabilitation games can be a good tool to support therapy for children with CP. Such treatment not only focuses on arm movement but also helps identify images, colors, and sounds. This treatment can also train arm movements within specific details. These games can encourage children to exercise because they become more motivated to perform the therapies<sup>12–14</sup>. In addition, another advantage is that patients can perform exercises at home with less restrictions<sup>7, 9, 15, 16</sup>.

In the present study, the comparison between before and after the experiment showed significant improvement in the speed and fine movements of the children. Only five patients were selected in the present study. However, more patients are required to obtain more reliable results. The main contribution of this research is to demonstrate that therapeutic games can provide additional help for patients with fine-movement problems in their arms and hands. Moreover, the devices used in these games are economical and flexible.

In future studies, the number of cases should be increased to ensure the validity of study results. Patients are able to play the rehabilitation game at home and thus achieve faster improvement. In addition, other studies on other types of disabilities should be conducted.

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