Case Report

Use of a Low-Cost, Commercially Available Gaming Console (Wii) for Rehabilitation of an Adolescent With Cerebral Palsy

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Background and Purpose. The purpose of this retrospective and prospective case report is to describe the feasibility and outcomes of using a low-cost, commercially available gaming system (Wii) to augment the rehabilitation of an adolescent with cerebral palsy.

Patient and Setting. The patient was an adolescent with spastic diplegic cerebral palsy classified as GMFCS level III who was treated during a summer session in a school-based setting.

Intervention. The patient participated in 11 training sessions, 2 of which included other players. Sessions were between 60 and 90 minutes in duration. Training was performed using the Wii sports games software, including boxing, tennis, bowling, and golf. He trained in both standing and sitting positions.

Outcomes. Three main outcome measures were used: (1) visual-perceptual processing, using a motor-free perceptual test (Test of Visual Perceptual Skills, third edition); (2) postural control, using weight distribution and sway measures; and (3) functional mobility, using gait distance. Improvements in visual-perceptual processing, postural control, and functional mobility were measured after training.

Discussion and Conclusions. The feasibility of using the system in the school-based setting during the summer session was supported. For this patient whose rehabilitation was augmented with the Wii, there were positive outcomes at the impairment and functional levels. Multiple hypotheses were proposed for the findings that may be the springboard for additional research. To the authors' knowledge, this is the first published report on using this particular low-cost, commercially available gaming technology for rehabilitation of a person with cerebral palsy.

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Virtual reality (VR) is defined as an immersive, interactive, 3-dimensional computer experience occurring in real time.[1] It presents users with opportunities to engage in multidimensional, multisensory virtual environments (VEs) that appear to be and feel comparable to real events.[2,3] Virtual reality systems typically involve hardware and software components. Users control an interface to enter a VE or setting for the simulation. Virtual reality systems offer clinicians the control over exercise duration, intensity, and environments that real-world tasks do not. Users in VR can perform tasks that they may not be able to execute safely or at all in real-world situations.[4] Virtual reality systems have been developed specifically for rehabilitation of upper-extremity use,[5–7] lower-extremity training,[8] and gait retraining.[8–11] Most of these systems are not commercially available and, when available, are very expensive. For this reason, low-cost, commercially available technologies, such as gaming systems, are being trial tested for rehabilitation applications.[12]

The feasibility and efficacy of using VR systems for individuals with cerebral palsy (CP), aged 8 to 15 years, have been explored by several investigators. Reid[13] found that children playing in a VE felt safe and were able to practice. In a comparison of 12 VEs, Reid[1] also found that playfulness was increased if the child had some control and was allowed creativity and persistence with the VE's task. When compared with standard physical and occupational care, students who practiced in VR had similar outcomes.[14] In contrast, VR was found to be superior to standard ankle exercises practiced at home for adherence, exercise repetition, and endurance, as well as to foot excursion measures.[15] Training in upper-extremity movements in VR was found to improve reaching behaviors and to produce cortical reorganization.[16] Improved visual-perceptual processing using VEs in isolation and combined with tabletop activities also was reported for children with CP.[17]

Interestingly, with the exception of the visual-spatial study, all of these studies were conducted using the IREX (Interactive Rehabilitation EXercise)* platform. This is a commercially available motion-capture VR system that was specifically designed for rehabilitation. Users wore gloves that were detected by a camera and embedded them in a 2-dimensional flat-space environment where they interacted with graphical objects. The VE was projected onto a large screen in front of the user. Only in one report[18] was gaming technology, the PlayStation 2 platform in combination with the EyeToy,† trial tested with children with CP. The low-cost PlayStation 2 gaming system has been shown to provide presence, enjoyment, usability, and performance comparable to the IREX for a variety of—but not all—patients.[2]

In their review of VR in rehabilitation, Weiss and colleagues[2] concluded that motion-capture systems show great promise for a variety of therapeutic goals, including improving functional activities and motor rehabilitation. They also identified some of the drawbacks of motion-capture VR systems, specifically lack of haptic (touch) feedback, an inability to have multiple players, the degree of presence afforded, and the high cost of those designed specifically for rehabilitation.

The limitations identified for the video motion-capture systems are addressed, in great part, by a commercially available VR gaming system that could potentially be used for rehabilitation, the Nintendo Wii.‡ This system uses a remote controller as the input into the VE. Unique features of the controller relative to other low-cost, commercially available gaming VR systems (such as the PlayStation 2 EyeToy) are its motion sensors and shape. Users hold the controller (or remote) in a manner that is congruent with the way the hand would hold and manipulate real-world objects (such as the handle of a racket). The controller has a sensor that measures the person's motions and maps them into the VE. It also provides the user with haptic feedback. This is the physical sensation connected with interacting with objects in the VEs.[19] Users feel a ball contacting a virtual racquet, although this sensation may not be identical to a real-world sensation. The sensation, however, is enhanced with auditory feedback. The Wii uses differences in the applied forces and accelerations of the remote to change the amount of feedback it provides to the user. Multiple players can simultaneously participate in a game scenario. Some of the games resemble real-world games such as tennis, golf, and boxing, requiring total body movement often congruent with real-world motions. There are many reports in the popular press about using the Wii in clinical settings; however, to date, there are no published reports on the use of the Wii for rehabilitation.

Although we have had a positive experience with a haptic-robot VR system to rehabilitate walking for people after stroke, we were frustrated with the cost and time delay from development and testing to implementation in the clinic. Therefore, we wanted to explore a portable, lower-cost, and commercially avail-

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‡ Nintendo Domestic Distributor, 15–15 132nd St, College Point, NY 11356.

able system that could immediately be trial tested in the clinic. We identified a candidate user, an adolescent with CP whose physical capabilities allowed him to use the Wii but whose functional limitations prevented real-life practice of the sporting activities provided by the Wii. We speculated that the practice of these activities would address his physical therapy goals, which included improving visual-perceptual processing, postural control, and functional mobility. The purpose of this retrospective and prospective case report is to describe the feasibility and outcomes of using the Wii to augment the rehabilitation of this patient using individual and group gaming sessions.

Case Description

Patient History and Examination

At the time of the intervention, the patient was a 13-year-old adolescent attending a summer program at a school for children with developmental disabilities. Based on a chart review, his past medical history included being born heroin dependent at 28 weeks of gestational age. He was diagnosed with spastic diplegic CP and delayed development. Additional diagnoses included severe asthma, requiring oxygen and the use of inhalers, and tonic seizure activity.

It was noted that, on several occasions in the patient's medical and educational chart, he had difficulty maintaining task focus and problem solving, displayed task-avoiding behaviors, and was easily distractible. A neurological evaluation was completed, and the findings suggested that he had poor motor planning, poor ability to sustain attention, and poor ability to complete tasks. Nonetheless, 14 months prior to the intervention, the findings of an assessment using an attention-deficit/hyperactivity disorder index were reported in the chart to be in the normal range. According to his therapists, during the school year before the intervention, there was a dramatic improvement in his attention. There was no specific explanation in the chart for this change. Findings from the Wechsler Intelligence Scale for Children (WISC-IV) showed significant difficulty with verbal comprehension, perceptual reasoning, processing speed, and number and letter sequencing. The interpretation of the WISC-IV findings classified him as predominantly in the borderline to extremely low range. His full IQ was scored as 79.

According to the patient's chart, during his re-evaluation (3 months prior to the intervention), he was described as having active movement in all extremities, with better isolated movement of the upper extremities relative to the lower extremities. He used his left upper extremity as his dominant functional arm. Posture in supported standing was described as semicrouched, with hip medial (internal) rotation and adduction. Sitting posture included a posteriorly tilted pelvis, laterally flexed trunk with convexity to the right and flexed posturing of the right upper extremity, and decreased loading through both lower extremities. He also had decreased range of motion in hip extension and lateral (external) rotation, knee flexion, and ankle plantar flexion; he had poor abdominal strength (force-generating capacity); and he lacked core stability. At that time, he was ambulating independently with bilateral ankle-foot orthoses and a posterior rolling walker throughout school, in his home environment, and for short distances in the community. This would classify him as Gross Motor Function Classification System level III.[20] For the previous 2 school years, he had been working on ambulation with bilateral forearm crutches in physical therapy. He ambulated with his bilateral forearm crutches up to 75 ft (22.9 m) with close supervision; however, he completed this task at a slow speed and occasionally lost his balance, requiring assistance to regain control. The projected physical therapy goals for the upcoming school year included: independent standing for 5 minutes using one forearm crutch while performing an activity; ambulating 200 ft (61 m) using forearm crutches with contact guard assistance without loss of balance; and upright midline sitting on a bench or bolster for up to 10 minutes, requiring fewer than 2 verbal cues.

This adolescent appeared to be a good candidate for trial testing the Wii gaming system. He was selected for several reasons, including having adequate functional hand skills to manage the Wii remotes, gross motor skills to work in either a sitting or standing position, and sufficient cognitive skills to follow directions, stay on task, and understand the games. Based on the physical therapy goals that involved trunk control and mobility combined with the challenges observed in the patient's ability to maintain attention, we felt that a gaming activity that engaged him and provided opportunities to remediate his physical limitations might be a useful adjunct to his therapeutic regimen. After obtaining consent from the adolescent's guardian, tests and measures and the intervention were administered.

Tests and Measures

Several standardized measures were used exclusively to characterize the motor control profile of the patient. These measurements were not repeated because they were not expected to change during the short interval of the intervention. Observations of posture confirmed the descriptions in the chart. Tests of visual-perceptual discrimination, postural control, and functional mobility were administered as outcome measures. The timing of administration of the pretesting and posttesting varied according to the measure and who was conducting the testing. Testing that we conducted was administered immediately before and following the intervention. Testing performed by the treating clinicians was administered at the scheduled re-evaluations for the patient in the school setting. It was our clinical hypothesis that he would exhibit changes in visual-perceptual processing and postural control because they would be directly addressed by the intervention. What we did not know was whether the training would transfer to his functional mobility.

To characterize the patient's motor control, we used the Quality of Upper Extremity Skills Test (QUEST)[21] and the Gross Motor Function Measure (GMFM).[22] These tests were selected because they have been validated for people with CP.[21]

The patient completed subtests D (standing) and E (walking, running, and jumping) of the GMFM prior to the third treatment session. High intrarater and interrater reliability (intraclass correlation coefficient [ICC]=.92–.99) have been reported for both subtests.[22] Subtest D includes items such as coming to a standing position from a kneeling position, standing independently, and reaching for objects on the floor from a standing position. On subtest D, the patient achieved a raw score of 12, with a total percentage of 30.77%. Subtest E includes items such as cruising, walking forward, stepping over objects, jumping, hopping, and stair climbing. On subtest E, the patient had a raw score of 21, with a total percentage of 29.17%. A score of 100% on each subtest indicates that the person can perform all of the activities. A child who is developing typically would receive a score of 100% on all subtests by the age of 5 years.[22]

Table 1.
Definitions of the Subtests of the Test of Visual Perceptual Skills, Third Edition, (TVPS-3)[27]

TVPS-3 Subtest	Definition
Visual discrimination	The ability to match, or determine exactly, characteristics of two forms when one of the forms is among similar forms.
Visual memory	The ability to remember for immediate recall (after 4 or 5 seconds) all of the characteristics of a given form and to be able to find this form from an array of similar forms.
Visual-spatial relationships	The ability to determine, from among 5 forms of identical configuration, the single form or part of a single form that is going in a different direction from the other forms.
Visual form constancy	The ability to see a form, and be able to find that form, even though the form may be smaller, larger, rotated, reversed, or hidden.
Visual sequential memory	The ability to remember for immediate recall (after 4 or 5 seconds) a series of forms from among 4 separate series of forms.
Visual figure-ground	The ability to perceive a form visually and to find this form hidden in a conglomerated ground of matter.
Visual closure	The ability to determine, from among 4 incomplete forms, the one that is the same as the completed form.

Prior to the third treatment session, the dissociated movements and grasp subtests of the QUEST were administered, which were deemed appropriate given the functional level of the patient. High test-retest reliability (ICC=.93–95) and interrater reliability (ICC=.91) have been reported for these subtests.[21] The patient's raw score for dissociated movements was 95.31, with a standardized score of 90.62, and his raw score for grasp was 81.48, with a standardized score of 62.96. For both subtests, the patient scored higher—64.06 (SD=22.20) for dissociated movements and 48.71 (SD=30.73) for grasp—than the oldest group of children in the validation study.[21] A score of 100% indicates perfect performance. The items of the QUEST are essential components of movement developed during the first 18 months of life.[21]

Outcome Measures

Visual-perceptual processing was tested because it is known to be impaired in children with CP.[23–25] Visual perception is a high-order system that allows people to perceive a world beyond their bodies and plan a vast range of different actions.[26] We hypothesized that training in the VE may enhance these processes and, in turn, may improve mobility. The Test of Visual Perceptual Skills, third edition, (TVPS-3) was selected because it is a nonmotor assessment of visual perception for individuals 4 to 18 years of age.[27] The TVPS-3 comprises 7 subtests arranged in order of difficulty from least difficult to most difficult. It includes categories of perception such as spatial relationships and figure-ground that are particularly pertinent to integrating perception and action. A description of each subtest is presented in Table 1. The test was administered by an occupational therapist who was masked to the intervention. Test-retest reliability for the overall test was reported as r=.97. Standard errors of measurement for the subtests range from 1.10 to 1.51.[28]

Scaled scores are calculated using a person's raw scores and chronological age. Scaled scores range from 1 to

Table 2.
Preintervention and Postintervention Test of Visual Perceptual Skills, Third Edition, (TVPS-3) Scores and Wechsler Intelligence Scale for Children (WISC-IV) Classifications

TVPS-3 Subtest	Preintervention		WISC-IV Classification	Postintervention		WISC-IV Classification
	Scaled Score	Percentile		Scaled Score	Percentile	
Visual discrimination	5	5	Borderline	12	75	Normal/average
Visual memory	8	25	Normal/average	10	50	Normal/average
Visual-spatial relationships	10	50	Normal/average	12	75	Normal/average
Visual form constancy	3	1	Extremely low	5	5	Borderline
Sequential memory	10	50	Normal/average	6	9	Borderline
Visual figure-ground	8	25	Normal/average	10	50	Normal/average
Visual closure	7	16	Low average	10	50	Normal/average

19 and are based on a population distribution with a mean of 10 and a standard deviation of 3. Percentile rankings provide a reflection of the performance of one patient compared with the population. Functional classifications such as the WISC-IV also can be used to further define a person's performance on the test. The patient's preintervention results are presented in Table 2.

The patient's overall standard baseline score of 86 was within 1 standard deviation of the mean from the normal distribution.[29] This score was slightly higher than that found in children with CP whose TVPS scores (an earlier version of the TVPS-3 was used) were more than 1 standard deviation lower than those of children who were developing typically.[29,30] His superior baseline score may be explained by his age, which at 13 years was higher than that of subjects tested by previous investigators.[28]

Postural control was examined using measures of weight distribution and sway collected during static stance with eyes open and with eyes closed on a Posture Scale Analyzer.[§] The system consists of 4 scales that are joined as a single plate on which a person stands. A computer connected to the system calculates weight distribution, center of pressure, and sway rates. Measurements for each condition were taken 3 times for 10 seconds. The patient stood on the PSA with the walker behind him. He was instructed to "stand as tall as possible and not hold on to your walker." This instruction was designed to encourage loading through the lower extremities to minimize support on the walker.

Validity of the weight measurements was established, using a scale, on 25 subjects who were healthy. There was a 0.7-lb (0.3-kg) measurement error (unpublished data). Test-retest reliability of the PSA also was measured in subjects who were healthy using a coefficient of variation and reported standard errors of measurement that ranged from 1% to 2% in the medial-lateral plane and 4% to 6% in the anterior-posterior plane.[31] As 3 trials were measured for each condition, we were able to calculate the coefficients of variation, which were 3% to 8% in the medial-lateral direction (for eyes open and eyes closed) and 1% to 30% in the anterior-posterior direction (for eyes open and eyes closed). The preintervention results are presented in Table 3.

Functional mobility measurements were extracted using retrospective data from the chart review. This method was selected to have repeated measurements relative to the patient's therapy goals by the same

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[§] Midot Medical Technology, Irus 276, Gan Ner, 19351 Israel.

Table 3.
Preintervention and Postintervention Measurements on the Posture Scale Analyzer (PSA)

PSA Measures	Preintervention		Postintervention	
	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
Percentage of body weight	96	89	97	98
Sway rate (mm/s)	103	143	40	64
Percentage of right/left weight distribution	39/61	31/69	37/63	51/49
Percentage of anterior/posterior weight distribution	74/25	71/29	55/45	73/27

rater over time. Because it was performed retrospectively, reliability was not established. His walking distance with forearm crutches, as measured by the treating physical therapist, was initially 30 ft (9.1 m) with moderate assistance (approximately 2 years prior to initiating the Wii intervention). It ranged from as little at 10 ft (3 m) with contact guard assistance to minimal assistance to as much as 150 ft (45.7 m) with contact guard assistance.

Intervention

The goal of the intervention was to determine the feasibility of introducing this novel gaming technology to address a specific patient's goals. We selected the gaming system based on several factors. First, the handheld interface to the virtual world reads acceleration changes to map the movements of the person into the gaming environment. This type of system encourages movements that can be performed in both sitting and standing positions. The patient was able to learn the movements in a sitting position and then practice them in a standing position. Second, there are stock games available in the system that can be analyzed for their biomechanics and motor control requirements. The games then were selected based on patient interest and task requirements. Third, it provides users with knowledge of performance (KP) and knowledge of results (KR). *Knowledge of performance* is information about the kinematics of the movement, and *knowledge of results* is information about the outcome of the movement,[32] which have been shown to improve performance and skill in children with CP.[33,34] Finally, it allowed for multiple users, and we were interested in probing how interaction with other users (in this case, the therapists and a child who was developing typically) would be received by the patient. Using a client-centered approach, the Wii Sports games were selected based on the patient's interest as well as the therapeutic goals addressing motor control and visual-perceptual processing. The games were played in a training or game mode in both sitting and standing positions. For games played in a sitting position, a therapist guarded from behind, occasionally stabilizing the chair. For games played in a standing position, the therapist guarded from behind or on the side to stabilize the posterior walker. A detailed description of each of the games selected, along with its therapeutic aim, is provided in the Appendix.

Each game had different motor control and visual-spatial demands. For example, golfing required judgments of force, distance, and figure-ground discrimination, with high accuracy constraints. Upper-extremity control was promoted by all games. The remote was held with the left (dominant) hand for the bowling game; with both hands for the baseball, tennis, and golf games; and with one hand holding a Wii remote and the other hand holding a nunchuk for the boxing game. Trunk control was promoted by all games. For example, the boxing game required midline trunk orientation and endurance of trunk muscles. The bowling game required trunk stabilization while moving a single upper extremity with varying degrees of force. The games played in a standing position emphasized balance with weight transfer between the lower extremities.

Treatment was administered during the summer session in addition to his regular therapies. The patient participated in 11 sessions over 4 weeks. Sessions ranged from 60 to 90 minutes. Individual games ranged from 5 seconds to 5 minutes. This dosing was selected based on the patient's availability, and it resembled a short, intensive trial of a new therapy. It is likely that frequency could be maintained but possibly not duration. The first 7 sessions focused on the patient using the system by himself. In the 8th session, a child who was developing typically worked with the patient. In the 11th session, he experienced 2- and 3-person games. During the treatment, he continued to receive his physical therapy (3 times a week) and his occupational therapy (2 times a week). He also participated in a 1.5-hour occupational therapy group.

Position and tasks were varied based on observation of performance. Doses of treatment were adjusted to increase duration, repetition, and complexity of tasks based on patient performance using observations of posture and movement as well as the performance in the VE. For example, the boxing activity required bilateral upper-extremity reciprocal movements that promoted midline trunk alignment. The boxing activity was selected early to establish good postural control before playing more challenging unilateral upper-extremity activities such as bowling or tennis.

Activities were stopped or modified when the therapists observed deterioration in the patient's physical performance, technique, or postural control resulting from overexertion. For the most part, the patient controlled the flow of activity. Rest periods lasted for the duration that it took the patient to reposition the Wii remote and adjust the settings for the next game. Training time was divided between sitting and standing positions and varied based on the patient's performance (Fig. 1). The distribution of time spent on each game is illustrated in Figure 2.

Outcomes

Outcomes were assessed at different times after training. A repeat TVPS-3

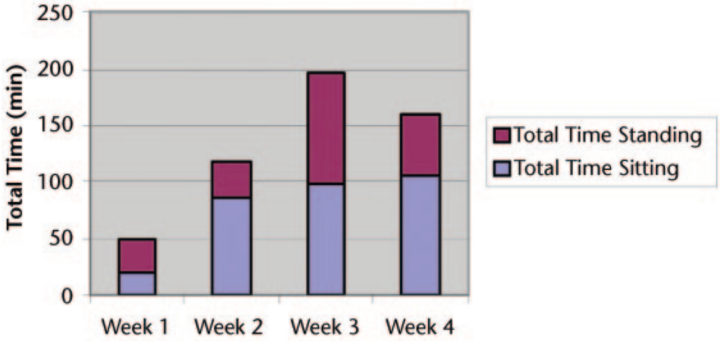

Figure 1.
Training distribution by position.

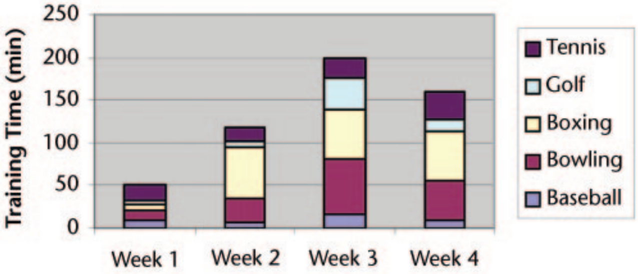

Figure 2.
Distribution of games for each week.

was administered by the occupational therapist approximately 1 month after the training. We retested the postural control measures 1 day after training, and walking was evaluated by the treating therapist during the training and approximately 3 months after the training ended.

Visual-perceptual processing improved in all domains except visual memory. Improvements ranged from a 4th percentile change in form constancy to a 70th percentile change in visual discrimination (see Tab. 2 for all visual-perceptual processing results).

Postural control improved in a variety of measures. There was greater loading on the lower extremities and less reliance on the walker during the eyes-closed condition. Center-of-pressure sway decreased by approximately 60% in both eyes-open and eyes-closed conditions. Medial-lateral weight distribution became more symmetrical during the eyes-closed condition and more symmetrical in the anterior-posterior direction with eyes open (see Tab. 3 for all postural control results).

Functional mobility (ambulation with the forearm crutches) was measured by the physical therapist during treatment sessions independent of the researchers. It increased during the training (from 15 ft [4.6 m] to 150 ft [45.7 m]) and continued to increase to 250 ft (76.2 m) after training (Fig. 3). This distance had never been achieved or maintained by the patient prior to training.

Discussion

The purpose of this case report is to describe the feasibility and outcomes of incorporating the Wii as an intervention for an adolescent with CP. Introducing the Wii for this student was feasible. His class schedule was adjusted to allow for 2 or 3 weekly training sessions, for a total of 11 sessions. The intervention was rendered over the summer when scheduling is more flexible in the school. The student was able to independently walk to the session. He arrived promptly and was engaged for the entire time. The sessions were supervised by 2 people (ie, professional-level [entry-level] DPT students, faculty, or a clinician who worked at the facility). Two people were required partly because all of the sessions were observed and documented. We speculate that a single person would be able to conduct the sessions, thereby increasing the feasibility of implementing this type of therapy in the clinic.

The clinic already had a television set in its therapy space, so only the purchase of the Wii would be required to continue the therapy initiated in the case report. An in-service training session that we provided to the clinic staff after the trial intervention elicited enough interest for them to make such a purchase. Other students were identified by the staff as being likely candidates to trial test a similar intervention.

Cognition and motivation were important considerations in selecting this particular patient. His IQ rating was low, and he had some reported attention deficits, both of which were previously identified as a limitation for VR training.[18] However, he had recently increased his attention and was motivated to try the system, partly based on his previous experience with commercially available gaming systems. Therefore, we believed that he would have the minimum attention requirements and, importantly, the motivation to address a variety of therapeutic goals. Consistent with previous work,[1] we enhanced his inherent motivation by

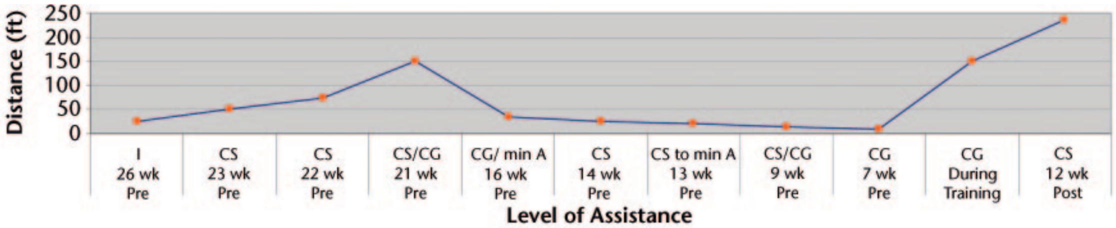

Figure 3.

Ambulation distance with forearm crutches measured during physical therapy sessions. The single peak of walking 150 ft (45.7 m) achieved 21 weeks prior to training was not replicated or sustained until after intervention with the Wii. I=intervention, CS=close supervision, CG=contact guard assistance, min A=minimal assistance, Pre=prior to training, Post=after training.

giving him control over task selection and creativity in the session planning.

The multiple-player capability of the system was feasible and facilitated social interaction and unexpected therapeutic benefits. In the 10th session, we introduced a child who was developing typically as a second player. During that session, we observed turn taking, strategy sharing, and encouragement. In the subsequent session, the patient completely changed his bowling strategy and reported that he used the strategy of the child who was developing typically. The change in strategy based on modeling may explain his improved bowling game score from 119 to 157 points, which was maintained in the subsequent session when he bowled 160 points.

The feasibility of long-term use may be enhanced by the system's multiple-player capability. During the ninth session, we observed a decline in the patient's enthusiasm and interest in the gaming system. He reported, "I had more fun in the beginning, but I still like it," and "I am OK with the games but new games would make it more fun." We introduced new players and observed that he maintained his interest in the task for 8 minutes without interruption and did not require verbal cues. A gaming system that accommodates multiple players could involve several patients working at once and may offer efficient options for therapy delivery.

It is important to highlight that essential clinical decisions were made by the therapist throughout the training, and—at least for this patient—it would not have been advisable or safe to have him train on his own. The feasibility of implementing some of the exercises at home, as has been done by other researchers,[12] however, would warrant further investigation.

The gaming intervention was designed to address 3 therapeutic goals: postural control, functional mobility, and visual-perceptual processing. Functional mobility was addressed indirectly by combining visual-perceptual processing, postural control, and endurance training in a standing position. We had speculated that improvements could be obtained for the outcomes that were trained directly. We were less certain whether there would be a positive transfer to walking.

We speculate that visual-perceptual processing improved because it was practiced in all of the games. The patient's greatest improvement was in visual discrimination, where his 75th percentile postintervention score placed him in the normal range. Improved performance on some of subtests, such as the 100% improvement in figure-ground, are easy to interpret based on the figure-ground relationships embedded in each of the games. These games are representative of real-world environments and require extracting relevant features from background information. For example, the golf game requires a player to locate the red flag and hole in a sea of green and trees. Other improvements, such as visual closure, are more difficult to explain. We do not know why the visual memory score decreased, which is the only score that did not improve. There is evidence in the literature that visual-perceptual deficits can be remediated for both children who are healthy and children with CP.[35] It is important, however, that visual-perceptual training occur in the context of action.

In this case report, the emphasis of the training was on performance of the task in the VE. This training approach stimulated motor behaviors that had visual-perceptual requirements rather than training visual-spatial perception in isolation. This training approach is consistent with the notion that it is necessary to engage the individual in the motor behavior to acquire the spatial processing ability.[35,36]

Postural control, measured by weight distribution and amount of sway in a standing position, improved after training. During the eyes-closed condition, the patient's weight distribution between the lower extremities became more symmetrical. The decrease in sway that was observed after training can be interpreted as a sign of increased stance stability. This finding is consistent with work by Shumway-Cook et al,[37] where massed balance training produced a decrease in center-of-pressure sway in children with CP. The training provided in this case combined massed practice of balance with vision and attention directed at the game rather than maintaining balance, which we believe stimulated the proprioceptive-vestibular system.

The proportion of time spent training in a standing position varied by week and ranged from a low of 35% to a high of 50%. The longest single training time in a standing position was 34 minutes. Interestingly, this time far exceeded the therapeutic goal of standing for 5 minutes while engaged in an activity set for the coming school year. Importantly, the therapist's suggestions for improving posture were secondary to cues for improving gaming performance. As with the visual-perceptual processing, attention was focused on the game and performance in the gaming environment rather than attending to posture. The duration and intensity of training facilitated by the engagement with the Wii games distinguish this balance intervention from those currently available to physical therapists as the standard of care.

Transfer of training from gaming to walking is a finding with important therapeutic implications, although these data should be interpreted with caution because they were collected from the patient's chart. Future studies should include a 6-minute walk test to measure walking endurance.[38] We speculate that both visual-perceptual processing and postural control training coupled with endurance may explain our patient's improvements in functional mobility. Other authors[37] have shown that training relevant elements of a balance task may transfer to the entire task. There also is work where training a visual-spatial task in the virtual world transferred to improved way-finding in the real world.[39] In people poststroke, training relevant lower-extremity features of gait in VEs has been shown to transfer to improved walking in the real world.[8] However, we are not aware of similar work with children with CP.

There are a variety of explanations for why our patient improved after training with the gaming system. One explanation may be the intensity of treatment. He certainly exceeded duration on task relative to his therapy sessions, as well as repetitions. The training also was task driven and required problem solving. These features of training have been shown to promote behavioral changes[40–42] as well as neural plasticity[16] in children with CP. Finally the multisensory feedback provided by the system may explain improvements in performance as well as learning.[33] The rich feedback included auditory, visual, and haptic information along with provision of KP and KR. All of these hypothesized mechanisms would be amenable to testing. In addition, it would be of interest to compare outcomes of training between this low-cost, commercially available system and others such as the Sony PlayStation 2.

Summary

A low-cost, commercial gaming system was trial tested in an adolescent with CP. He participated in 11 training sessions to augment his existing rehabilitation program, 2 of which included other players. The feasibility of using the system in a school-based setting during the summer session was supported. Improvements in postural control, visual-perceptual processing, and functional mobility were measured after training. To our knowledge, this is first published report on using the Wii to augment therapy for a person with CP.

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Appendix.

Wii Sports Games Descriptions and Therapeutic Aims[a]

Activity Mode	General Description	Therapeutic Goal/Rationale and Feedback
Tennis game, sitting and standing, duration=1–2 min	Tennis matches are doubles games in which the game player controls both of the players on his or her team by holding the remote like a racket with one or both hands and swinging. A game player can play against the computer or an opponent. A single game, best of 3, or best of 5 games can be played. The computer positions the player in the correct spot to hit the ball. The game player is responsible for the type of swing (eg, forehand, backhand) and the timing, angle, and speed with which his or her player contacts the ball on the screen. The player serves the ball, receives serves, and volleys until the ball is missed or hit out of bounds.	Increase trunk control and endurance while reaching across the midline of the body Incorporate trunk rotation into the UE movement Increase hand-eye coordination and attention FB KR: haptic and auditory FB is provided as the player hits the ball KR: visual and auditory FB is provided in an instant replay of the volley after a point is awarded
Tennis training, sitting and standing, duration=5–20 s	The training activities consist of returning continuous serves from the computer's ball machine, hitting a ball to a targeted area at the end of the court, and hitting a target on a wall. These training games are relatively short, depending on the skill level of the game player and are terminated once the player misses a serve, hits a ball out of bounds, does not hit the ball to the targeted area, or fails to hit the ball after the first bounce. The training activities are played similar to the actual game by holding the remote and swinging it like a tennis racket.	Improve trunk control during short bursts of UE motions Promote segmental trunk rotation during unilateral UE movements while crossing midline Increase attention and hand-eye coordination FB KR: haptic and auditory FB is provided as the player hits the ball KR: visual and auditory FB is provided in an instant replay of the volley after a point is awarded
Boxing game, sitting, duration=3 min	Boxing matches are played against a computer or an opponent. The matches are terminated at the end of the 3 rounds or after a knockout. The Wii remote is connected to a nunchuk controller, with one held in each hand. The player punches and blocks the opponent's punches while holding the remotes in his or her hands to fight against the opponent on the screen. Once a player loses all his or her pieces, the player is knocked down and has 10 counts to get up. After a certain number of knockdowns, the player is considered to be knocked out and the match is over.	Maintain an erect, midline posture while performing a bilateral UE task that requires the player to reach away from his or her center of mass Improve core stability Improve attention and UE coordination FB KR: visual FB for the player's and the opponent's power level is displayed in a pie chart that decreases in pieces when the player or opponent is hit KP about arm movement trajectory KR: haptic FB is provided when opponent is hit
Boxing training, sitting, duration=1 min	Training sessions consist of punching a bag, dodging balls, or hitting the trainer's gloves.	Maintain an erect midline posture for 1 min while performing a bilateral UE activity that requires the player to reach away from his or her center of mass Improve core stability Encourage dissociated movement of the head and trunk during dodges FB Punching bag KR: visual FB with pie chart as above Haptic FB indicates a successful hit Boxing and dodgeball Bandwidth and KP FB: haptic sensation when player hits opponent rather than when glove or ball hits the player

(Continued)

Appendix.
Continued

Activity Mode	General Description	Therapeutic Goal/Rational and Feedback
Bowling game, sitting and standing, duration=5–17 min	Bowling games can be played by a single player or against multiple players. Bowling games consist of 10 frames. The game is played by holding the remote in the dominant hand, swinging the remote while holding down the B button in the frontal plane as if one were bowling, and releasing the B button at the top of the swing to release the ball. The player changes the trajectory and starting position of the ball by using the buttons on the remote before swinging.	Endurance and balance in a standing position using the posterior rolling walker while performing a unilateral UE task Incorporate trunk rotation into the swing Eye-hand coordination, attention, and motor planning FB KP visual display of speed and trajectory of ball KR auditory and haptic FB provided when player makes a strike KR visual instant replay
Bowling training, sitting, duration=2–3 min	Bowling training games consist of hitting various combinations of pins (eg, splits that are set up on each lane, avoiding randomly placed obstacles on the lane, and knocking down as many pins as possible when an increasing number of pins are presented).	Endurance and balance in a standing position using the posterior rolling walker while performing a unilateral UE task Incorporate trunk rotation into the swing Eye-hand coordination, attention, and motor planning FB KP visual display of speed and trajectory of ball KR auditory and haptic FB provided when player makes a strike KR visual instant replay
Baseball game, sitting and standing, duration=8–10 min	The baseball game consists of 3 innings in which the player alternates between batting and pitching. When up at bat, the player bats for every player on his or her team by holding the remote with one or both hands and swinging it like a bat. The player is responsible for the timing, the force, and the direction of the swing. In the outfield, the player is only a pitcher, as the computer automatically controls the other player. Pitching is done by holding the remote in an upward direction and moving the arm in a pitching motion.	Maintain proper sitting or standing posture without loss of balance while performing a task with the left UE Improve timing Increase attention and hand-eye coordination FB (batting) KR haptic and auditory FB provided when contacting the ball, visual trajectory of the ball
Baseball training, sitting and standing, duration=2 min	Training activities consist of practicing the timing of the swing and hitting the ball toward a specific section of the field.	Maintain proper sitting or standing posture without loss of balance while performing a task with the left UE Improve timing Increase attention and hand-eye coordination FB (batting) KR haptic and auditory FB provided when contacting the ball, visual trajectory of the ball
Golf game, sitting and standing, duration=3–21 min	Golf games are 3, 6, or 9 holes The game is played by holding the remote pointed downward with one or both hands, holding down the A button, and swinging the remote as if it were a golf club. On the screen, there is a map of the hole and a swing gauge for visual FB. The player can take as many practice swings as necessary before taking the actual shot. Before swinging, the player can change the type of club and the trajectory of the ball. The objective of the game is to get the ball in the hole in as few strokes as possible.	Maintain a midline, erect sitting posture while performing a task with the left UE that requires cognitive planning Increase attention and eye-hand coordination FB Bandwidth FB: haptic FB is provided when the player's swing is not fluid or when the force of the player's swing exceeds the target on the gauge for that shot KR visual FB of ball trajectory and endpoint location on the green
Golf training, sitting and standing, duration=2–3 min	Training games consist of driving the ball onto the green, putting the ball on the green, and trying to earn points by hitting a targeted area. Each training game has 10 swings. These drills resemble the actual game. The map and gauge are displayed on the screen.	Same as the golf game; in addition, the player can practice the individual parts of golf (driving and putting) FB Same as the golf game; in addition, KR is provided as haptic FB when ball misses the edge of the hole

[a] FB=feedback, KP=knowledge of performance, KR=knowledge of results, UE=upper extremity.