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Augmenting pediatric constraint-induced movement therapy and bimanual training with video gaming technology

Andrew M. Gordon[a,*] and Sandra Y. Okita[b]
[a]*Department of Biobehavioral Sciences, Teachers College, Columbia University, New York, NY, USA*
[b]*Department of Mathematics, Science, and Technology, Teachers College, Columbia University, New York, NY, USA*

Abstract. Cerebral palsy (CP) is the most common cause of physical disability in childhood. Hemiplegia is among the most common forms of CP and the resulting impaired hand function is one of the most disabling symptoms, affecting self-care activities such as feeding, dressing, and grooming. To date, evidence-based treatments are limited. Recent approaches, however, have capitalized on findings that show children with hemiplegia have residual motor capabilities and neuroplastic changes in nervous system function that emerge and improve with practice. Here the etiology and neural basis of hemiplegic CP is first briefly reviewed, followed by a description of the residual motor capabilities in the involved upper extremity and the potential role of intensive practice. Two promising approaches that target residual motor function, constraint-induced movement therapy (CIMT) and bimanual training, are then described. Recent evidence suggests that such task-oriented training approaches to rehabilitation are enhanced when the tasks are meaningful to the performer. Increasingly, this means use of current technology, specifically video gaming, to maintain salience and motivation and target specific motor impairments. Thus a method for using commercially available video gaming, including the Nintendo Wii to augment such intensive treatment approaches is described. It is suggested that with such intensive treatment programs, gaming can be an important compliment to, but not a replacement for, salient task-oriented activities in the real world and that video gaming and virtual reality training will be an important part of future rehabilitation efforts.

Keywords: video game console, Nintendo Wii, computer game, virtual reality, virtual environment, rehabilitation, cerebral palsy, task-oriented training, upper extremity, hand, bimanual training, constraint-induced movement therapy

1. Introduction

Cerebral palsy (CP) is the most common cause of physical disability in childhood, with hemiplegia, characterized by motor impairments mainly lateralized to one side of the body, being one of the most common substypes. The resulting impairments in upper extremity (UE) movement may greatly impact daily function, particularly those involving bimanual activities. Traditional therapeutic approaches largely have not proven successful at improving UE function. Recent approaches, however, have capitalized on findings that show children with hemiplegia have residual motor capabilities and neuroplastic changes in nervous system function that emerge and improve with practice. Salient age-appropriate tasks such as video gaming may enhance such approaches.

In the first half of this paper we briefly describe the etiology and neural basis of hemiplegic CP, followed by a description of residual motor capabilities in the involved UE and the potential of intensive practice at eliciting the residual function. We then describe two recent task-oriented approaches that capitalize on residual function, constraint-induced move-

*Address for correspondence: Andrew M. Gordon, Ph.D., Department of Biobehavioral Sciences, Box 199, Teachers College, Columbia University, 525 West 120th Street, New York, NY 10027, USA. Tel.: +1 212 678 3326; Fax: +1 212 678 3322; E-mail: ag275@columbia.edu.

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ment therapy (CIMT) and Hand-Arm Bimanual Intensive therapy (HABIT). Recent evidence suggests that task-oriented approaches to rehabilitation are enhanced when the tasks are salient to the performer. Increasingly, this means use of current technology, specifically video gaming, to maintain salience and motivation and target specific motor impairments. Thus in the second half of this paper we describe the potential benefits of video gaming, the choice of gaming platforms, and finally examples of how commercially available video gaming can be used to enhance intensive treatment approaches such as CIMT and HABIT.

2. Hemiplegic cerebral palsy

Cerebral Palsy (CP) is a development disorder of movement and posture causing limitations in activity and deficits in motor skill [7]. The impairments in movement coordination are attributed to non-progressive disturbances in the developing fetal/ infant brain. CP has an incidence of about 2–2.5/1000 live births. Spastic hemiplegia is characterized by motor impairments mainly on one side of the body and accounts for 30–40% of new cases (e.g. [61,95]). Hemiplegia CP is usually the result of middle cerebral artery infarct, hemi-brain atrophy, periventricular white matter damage, brain malformation or posthemorrhagic porencephaly (e.g. [11,23,82,113]). The integrity of the motor cortex and corticospinal tract (CST) underlying skilled dexterous hand movements is often compromised (e.g. [31,70,71,96,97]). Unilateral damage to motor areas may result in a failure of the affected CST to establish and maintain normal terminations in the spinal cord [41,52,75,76].

The CST damage results in impaired development of skilled independent finger movements and hand dexterity (e.g. [14]). The involved UE often exhibits abnormal muscle tone with posturing into wrist flexion, ulnar deviation, elbow flexion and shoulder internal or external rotation (e.g. [14]). Often there is weakness and sensory disturbances, which further impact fine motor skills [14,47]. Since many activities of daily living involve both hands, impaired hand function is one of the most disabling symptoms of hemiplegia [93]. Children with hemiplegic CP often compensate and neglect the more affected extremity, which can lead to further deficits [41]. Strong evidence-based treatment approaches are unfortunately lacking (see [3,13,69]).

3. Residual motor capabilities and motor learning

The mechanisms underlying impaired hand function in children with CP have been examined in a series of studies on prehensile force control [30,35,37–40,46, 48,49,54]. These studies focused on the sensorimotor mechanisms underlying fingertip force control during grasping. Impairments in temporal and force control, simultaneity of fingertip force application, excessive forces less adapted to the object's physical properties and impaired motor planning were documented [see [52] for review]. During the course of these studies it was noted anecdotally that hand function improved markedly during the course of a one-hour testing session. This led to the systematically study of the effects of extended practice by asking children with CP to repeatedly lift an object of a given weight. It was shown that the impairments in force regulation during grasp are partially ameliorated with this extended practice [30,46]. Interestingly it was also shown that lifts of an object with the non-involved extremity facilitates subsequent lifts with the involved extremity [48,49]. This suggests a potential role of the non-involved extremity in facilitating learning of motor skills in the involved extremity.

Together, these lines of evidence did not support traditional clinical assumptions that motor impairments in CP are static. In fact several studies have noted early and continuing development of hand function in children with CP [34,42,45,59,65]. Importantly UE performance in children with CP may improve with practice and development and may be amenable to treatment. We next turn to the prevalent method of providing intensive practice, CIMT.

4. Constraint-induced therapy

There is considerable basic science underlying the theoretical basis of applying intensive practice-based models to rehabilitation. Work in primates showed that unilateral pyramidal tract lesions or deafferentation decreases spontaneous limb use and quality that could be partly ameliorated if the unaffected limb was restrained (e.g. [105,109]). This work provided the basis for subsequent studies of "forced use" in adults with hemiparetic stroke by Wolf and colleagues [83,117, 118]. The technique was refined by providing 6 hours of structured activities incorporating principles of behavioral psychology (shaping), and this active intervention become known as "constraint-induced movement therapy" (CIMT) [106,108]. There have since been numerous studies of CIMT in adults with hemiparesis. In one of the first multi-site randomized control trials in physical rehabilitation, Wolf and colleagues [119] found positive outcomes of CIMT across a large number of adults with hemiparetic stroke (see [8,29,107]).

Since children with hemiplegia also often neglect their affected UE and have residual motor capabilities that emerge with practice, at first thought, it seems that CIMT would be an ideal way to provide practice. Although there are many case studies and small-sample reports, CIMT has not been studied in CP nearly to the same extent it has been in adult stroke. Nevertheless, findings to date have been largely positive across a variety of ages utilizing different methodologies and outcome measures (e.g. [10,19–21,33,40,50, 51,79,101,104,114] [reviewed in [17,36,63]]. While some investigators [103] have claimed that greater improvements are seen using the more intense (adult) models with a cast worn continuously for 3 weeks, there is no empirical evidence with standardized measures supporting these claims. Positive outcomes using standardized measures have been reported using much more child-friendly approached using far less restrictive devices (mitts) during just two hours per day [40]. Furthermore, as seen in Fig. 1, the time to complete the Jebsen-Taylor Test of Hand Function significantly decreased after an initial two-week constraint intervention, with a similar decrease occurring after a second treatment one year later [19]. Thus one can conceive that administering CIMT through repeated, less-intensive bouts as appropriate throughout development would be equally beneficial without being overly invasive.

Despite the potential benefit of CIMT, there are several conceptual problems in applying it to children. First, CIMT was developed to overcome *learned* non-use in adults with hemiplegia. Children with hemiplegia must overcome "developmental disuse," whereby they may not have ever learned how to use their involved extremity during many tasks, and therefore may need to learn how to use it for the first time. Thus, treatment must be developmentally focused, and take into account principles of motor learning. In addition, restraining a child's non-involved extremity (especially with casts) is potentially invasive, and thus CIMT should not be performed on young children with the same intensity as in adults since continuing maturation of CST connections underlying movement of the non-paretic UE may depend on activity of that extremity. Finally, CIMT focuses on unimanual impairments, which do not impact functional independence and quality of life greatly since these children maintain a well-functioning UE (see [93]). Children with hemiplegia have impairments in coordination of the two UEs (e.g. [56,66,98,99,112,111]) as well as general impairments in motor planning [100], which may be functionally important. Thus, rehabilitation should perhaps focus on increasing functional independence by improving use of both UEs in cooperation.

5. Bimanual training in children with CP

Normal development of UE function is the consequence of activity-dependent competition between the two sides with the more active side "winning out" over the less active (damaged) side [41,76]. Balancing activity of the two sides after unilateral brain damage may restore motor function, normal anatomical organization of the CST and the motor representational map in primary motor cortex in the developing kitten [44]. Principles of motor learning (practice specificity) would suggest that the best way to balance activity of the cortices and achieve improved bimanual control would be to practice bimanual control directly. There is emerging evidence that other forms of bimanual training may be efficacious in adults with hemiparesis (e.g. [16,91]), which may increase ipsilesional M1 excitability and transcallosal inhibition from ipsilesional to contralesional M1. These adult protocols largely employ repetitive non-functional tasks (i.e., are not child-friendly), and thus there is a need for an intensive bimanual training protocol that is child-friendly. The limitations of CIMT and rationale for bimanual training described above drove the development of a form of intensive functional training, Hand-arm bimanual intensive therapy (see [18]). HABIT aims to improve the amount and quality of involved UE use during *bimanual* tasks [for detailed description, see [18]]. HABIT retains the two major elements of pediatric CIMT (intensive structured practice and child-friendliness) and engages the child in bimanual activities 6 hours/day for 10-15 days in a day camp setting. Importantly, however, there is no physical restraint and HABIT involves task-oriented training to achieve meaningful goals. Task demands are graded to ensure success and activities of increasingly complex coordination are provided by requiring greater speed or accuracy, or requiring more skilled use of the involved UE (for example, transitioning from activities in which the involved UE is used as a passive stabilizer to activities where it is used as an active ma-

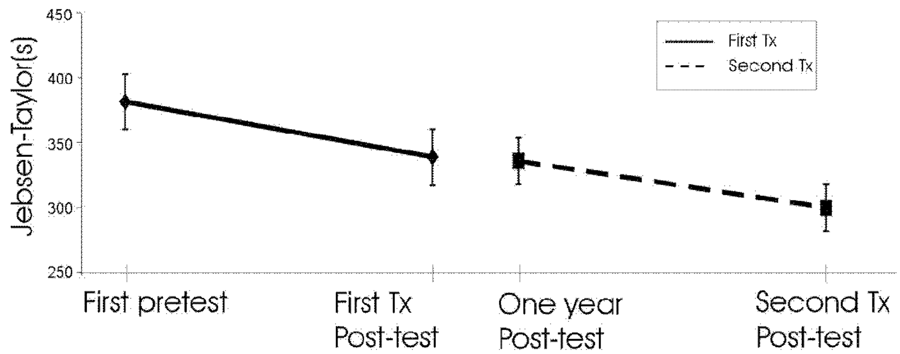

Fig. 1. Mean ± SEM time to complete the 6 timed items (writing excluded) of the Jebsen-Taylor Test of Hand Function at before and after the first CIMT treatment (Tx), 12 months later and following a second Tx. Modified from [19].

nipulator), (see [72,73]). Positive reinforcements, intermittent knowledge of results and reward are used to motivate performance and reinforce target movements.

Two studies have provided preliminary support for the efficacy of HABIT. The first was a randomized control trial of HABIT [55] on twenty children with hemiplegic CP between the ages of 3.5 and 14 years. Children who received HABIT had significantly improved quality and quantity of bimanual UE use as determined with the Assisting Hand Assessment (AHA [40,64,72, 73]), accelerometry [110] and kinematics (see [66]).

Clearly training without a restraint requires less intensive manipulative movements than CIMT since the involved UE is being used as a non-dominant assist. Is there a cost in treatment efficacy? The second study suggests that there is not. CIMT and bimanual training were compared directly [53], with similar improvements demonstrated for each group from the pretest to the post-test on the Jebsen-Taylor Test of Hand Function, the AHA and frequency of UE use (Fig. 2). The results show that improvement is not dependent on use of a restraint.

6. Incorporating technology into CIMT and bimanual training

Both CIMT and HABIT are task-oriented approaches to training based on models of motor learning and control and behavioral neuroscience [116]. In particular, these treatment approaches address activity limitations, which are of paramount importance to individuals with CP. These approaches are directed at enhancing manual skills. Efficacy may be dependent on: 1) intensity of practice, 2) targeting known deficits in movement coordination inhibiting function, 3) practice specificity (e.g. [67], 4) types of practice, 5) feedback, and 6) principles of neuroplasticity (practice-induced brain changes arising from repetition, increasing movement complexity, motivation, and reward). Practice must be progressively challenging [81,85], involve active problem solving [120], and importantly maintain meaningfulness [6]especially given the long duration of training associated with these approaches (e.g., 60–90 hours). In fact, a recent study in stroke indicates that there is no obvious relationship between intensity of treatment and efficacy unless the nature of what is practiced is included [120]. So for children, what constitutes "meaningful"?

As part of an ongoing randomized trial of HABIT and CIMT, we identified that nearly 80-% of participants between the ages of 5 and 10 years play video games (unpublished data). Other studies have reported children play video games on average 8 hrs/week [25]. Thus for rehabilitation protocols involving long hours such as CIMT and HABIT to remain effective in light of the importance of task salience, they cannot remain static; rather they must constantly evolve to include activities that are meaningful and enjoyable, including video gaming.

7. Potential benefits of video gaming

There are several benefits to bringing videogame graphics, Virtual Reality simulations, and narratives into children's physical rehabilitation. Video game technologies can diversify task activity, direct their attention toward specific goal-oriented movements, and motivate children to engage in repetitive tasks. Repetitive tasks can become more goal-oriented by adding a narrative and scoring points (e.g. participating in a ten-

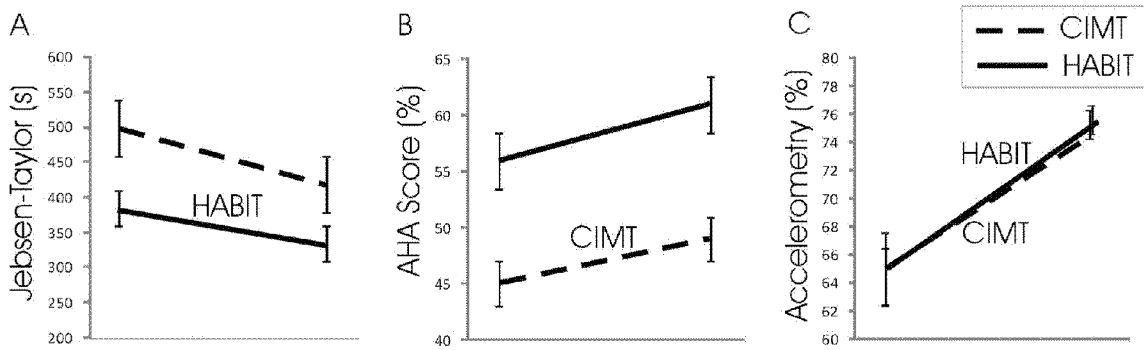

Fig. 2. Mean ± SEM A) time to complete the 6 timed items (writing excluded) of the Jebsen-Taylor Test of Hand Function, B) Assisting Hand Assessment Scaled Score and C) % time each UE moved during the AHA measured using accelerometers for children receiving CIMT (dashed lines) and HABIT (solid lines). Adapted from [53].

nis tournament). Such simple features may act as an extrinsic motivator to achieve rehabilitation goals, or act as a distraction from effortful movements. Another approach would be manipulating the game environment (e.g., balancing on tightrope, chased by a beast) to influence the child's behavior [4].

It has been suggested that actional immersion in a video/virtual environment may allow individuals to produce virtual movements that are not attainable in the real world. This has novel intriguing consequences and may enhance learning [5,26]. Gaming activities can provide a wide range of learning opportunities that may act as an intrinsic motivator that contributes to personal meaning. Simulated experiments in VR environments can help children develop reasoning and metacognitive skills [92]. Ideally the physical training would transfer as a behavior from the gaming world to the real world. For example, a guided discovery VR game on physical fitness or self caring may provide a felicitous environment that allows the child to "build" his or her own rehabilitation world rather than passively partake in a given situation. This allows the child to visualize their behavior, reason about the situation, and experience the causal chains from their actions. Ideally the gaming activity would then help bridge the link between the gaming world and real world, so that the child is motivated enough to continue physical rehabilitation on their own.

There are also social benefits to gaming. Children can create group activities that encourage peer support when exercising both cooperatively or competitively. Some successful social networks in VR environments such as Second Life [80] and Active Worlds, [28] often provide space for support group activities (e.g., Brigadoon Island [57] in Second Life is for children with Asperger's Syndrome).

8. Choice of gaming platforms

The choice of gaming platforms, consoles, and specific software needs to take into account 1) initial abilities of the learner, 2) specific motor impairments to be targeted, 3) the extent to which therapy is directed at one or both UEs, 4) the ability to create increasingly challenging movements rather than compensations, and 5) the interest of the child. Although use of virtual reality-based and video gaming protocols are increasingly being used in rehabilitation (e.g. [15,22,60,115, 122], presently there is a dearth of evidence of efficacy of the therapy by itself in CP. We propose that like HABIT and CIMT, it is just another means of engaging task-oriented training, but one that is potentially beneficial in maintaining interest and providing reward.

Two general approaches are used to incorporate video-based or virtual reality (VR) training into pediatric rehabilitation protocols, namely devising software and hardware protocols that target specific impairments or elicit specific movements, and utilizing existing commercially available platforms.

9. Custom-designed Virtual environments

While commercial game consoles are rarely built on personal history or experience, VR environments have been quite successful at personalizing gaming activities. Recent research has found that experiences in VR environments influence behaviors in the physical world [2,86,90,121]. For example, Fox and Bailenson [43] found that creating an ideal "self" model in VR (e.g., a physically fit avatar of yourself in VR) can motivate individuals to exercise more and modify health practices (e.g., exercise more on the treadmill). A VR environment can be designed to encourage motor learning and bimanual training. VR systems can produce sample movements that reflect needs of a child, or model movements with exaggerated features that could only be possible in the VR environment.

Virtual Reality (VR) environments can help children experience different point of views (e.g., first person, third person, birds-eye view) in relation to physical movements. VR simulations seem to be "real enough" to promote the therapeutic process of habituation or influence behavior change. In an interesting study, students learned Tai Chi movements in a VR environment [4]. Sensor devices recorded the student's physical actions, and mapped the movements onto their avatar in the VR environment. The student was able to overlap their avatar onto the instructor's avatar to self-correct movements in real-time. Advancement in sensor technology and computer processing speed has also changed the way we can collect credible data from game consoles.

Custom designed platforms may be especially useful for eliciting successful movements that may not be attainable in the physical environment by altering the gain of required movement to virtual movement [89]. Using this approach specific impairments could be targeted (e.g., wrist supination) by creating games requiring such movement, again adjusting the ratio of required to displayed movements. VR has been used in pediatric populations, including for CP, autism, fetal alchol syndrome, attention deficits, and pain managements (see [84]) with varying levels of evidence of efficacy. These approaches are indeed feasible for use in CP [87] and promising [78,102]. Snider and colleagues [94] recently reviewed and analyzed 13 studies of VR training in CP (all but two conducted by Professor Denise Reid at the Neurorehabilitation and virtual Reality Laboratory at the University of Toronto). Overall the analysis indicated positive outcomes of at least one measure for all but one study [94]. It was determined that the evidence for the effects of VR on body structure and function and personal factors such as motivation was conflicting but generally positive. There was not strong evidence for increasing activity and participation. The majority of studies were observational or case reports with small sample sizes, and thus despite promise, the current level of evidence is poor [94].

However they must maintain the same principles described above (especially salience) for successful physical rehabilitation. An important caveat in the mean while is that in comparison to the commercial game console the cost of building and programming devices that are enjoyable, flexible and can progress suitably with improvements to maintain sufficient challenge.These devices and games must address an array of movement impairments across a variety of ages since CP is a heterogeneous group of disorders. However, recent improvement in graphics techniques, computing power, and inexpensive webcam-based tracking system are making VR systems more affordable for patients. Yet there is often a considerable delay between the development and testing and the clinical implementation of such technology.

10. Application of commercially available platforms

The second approach to applying video gaming to rehabilitation involves using or modifying commercially available gaming equipment. While commercially available motion capture VR systems tailored specifically for rehabilitation do exist (e.g., Interactive Rehabilitation exercise (IREX), Gesturetek Health, Toronto), the initial cost may prevent wide-scale application in the short-term. Thus commercially available, mainstream gaming consoles have the distinct advantage of constantly being updated to maintain the interest of children, are familiar to most children and the initial financial investments are minimal compared to the wide array of devices and games. However, a huge limitation is that these devices were not created to elicit specific movements that are necessarily impaired in children with CP. Furthermore, they may not have sensors that are sensitive enough to translate subtle movement improvements into improvement in game performance. During free play, children are likely to choose games or consoles that can either be performed with one (nonparetic) UE or require minimal (stabilization) movements of the affected UE. So the utilization of these devices requires careful planning and structuring of the task.

Despite considerable attention of using the Wii for rehabilitation in mainstream media, surprisingly there is only one published report of efficacy to date. Deutsch and colleagues [27] performed a case study of an adolescent with CP. The results suggested that Wii play improved visual-perceptual processing and postural control [27]. Considerable more research is required to determine efficacy of the Will in rehabilitation for CP.

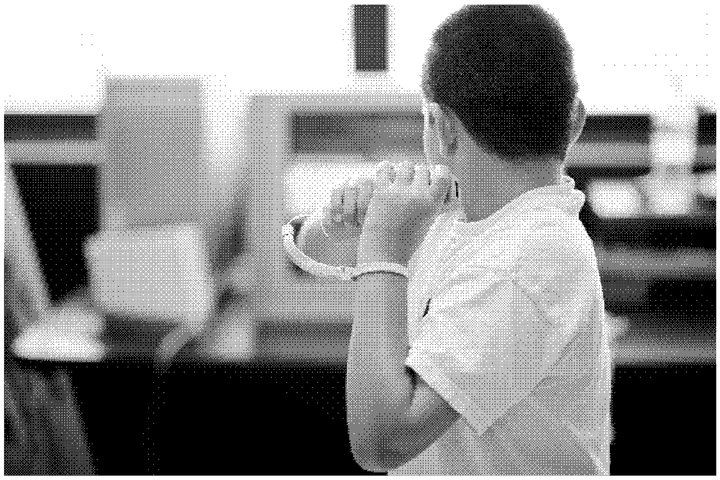

Fig. 3. Example of a child playing Wii Sports Baseball.

11. Examples of how commercially available platforms can be adapted for CIMT and bimanual training

For our own intensive CIMT and HABIT protocols, we chose the latter approach for feasibility reasons. Children engage in play of commercially available video/computer games for up to half an hour per day, typically at the end of the day when attention at other tasks may wane. Thus gaming can also be used to motivate performance of other tasks earlier in the day. Games and platforms are chosen based on: 1) joint movements with pronounced deficits, 2) joint movements that interventionists believe have the greatest potential for improvement, and 3) child preference for video games that that have similar potential for improving identified movements. Video game technology has become a promising tool in assisting physical rehabilitation, partly due to the variation in available input devices used for gaming. We chose three gaming platforms to work from depending on the child's age, whether they were in the HABIT or CIMT intervention, and their specific interests and movement deficits.

For children below five years, the Clickstart® (LeapFrog Enterprise, Emeryville, CA) is used. The console consists of an age-appropriate keyboard and mouse that can be connected to a standard television. Games can be selected requiring increasingly rapid key presses, rapid and accurate mouse movements or a combination of both depending on which intervention the child is in and whether deficits to be worked on require proximal arm movement accuracy, digit individuation or coordination of both UEs. The mouse can be built up with tape and placed on slippery or sticky (e.g., Dycem) surfaces to grade the activity to ability and increase difficulty as performance improved.

For children above 5 years, the PlayStation Portable® (PSP, Sony Computer Entertainment, Tokyo, Japan) and Nintendo's Wii (Nintendo, Minami-ku Kyoto, Japan) are employed. The PSP can only be used for bimanual training since it generally requires pushing buttons with both hands. Games can be chosen that elicit increasingly complex actions of both hands as opposed to simply stabilizing the console with one (involved) hand and using the non-involved hand for manipulative components. Specific instructions necessitating use of both hands are sometimes necessary given children's' often strong desire to compensate use with the non-paretic UE. The grip surfaces can be built up with tape as necessary and buttons made easier to hit by attaching plastic surfaces of varying size over them and grading them as manipulative abilities improved.

The popular Nintendo Wii can be used for children in the CIMT and bimanual training groups above 5 years of age. Wii use has been found to increase energy expenditure primarily through use of the upper extremities [27,58]. The Wii remote has evolved the joystick to a wireless device that can be controlled by mimicking natural gestures. The main controller (Wiimote) elicits grips similar to those of real-world objects (see Fig. 3). It consists of a hand held remote with a trigger and surface button with proximal action of the arm (pointing, rolling, swinging) controlling the video game via three accelerometers and an infrared pointer that communicates with the controller via Bluetooth [77].

Table 1
Example of using Nintendo Wii for therapeutic goals

Therapeutic goal	Treatment	Example activities	Example Wii games
Eye-hand coordination	CIMT & HABIT	Baseball, tennis, boxing, paddle games, shooting, crossbow	Jenga, Wii Sports, Warioware, Jenga, Smooth Moves, Mario & Sonic at the Olympics, Wii Play
Hand-arm coordination	CIMT & HABIT	Bowling, shooting, ball games	Wii Sports
Increase range of motion	CIMT & HABIT	Baseball, boxing, bowling	Wi Sports
Bimanual coordination	HABIT	Simulated running, simulated swimming, cross-bow, Boxing,	Wii Sports, Mario & Sonic at the Olympics, Rayman Raving Rabbids
Trunk control while reaching across midline	CIMT & HABIT	Tennis, baseball	Wii Sports
Trunk rotation	CIMT & HABIT	Tennis, baseball, bowling	Wii Sports
Core stability		Boxing, bowling, Baseball, golf	Wii Sports
Dissociating elbow/shoulder	HABIT	Boxing, golf, pool	Wii Sports, Wii Play
Wrist supination	CIMT & HABIT	Paddle games, driving games, drumming, orientation matching, Laser Hockey, car racing	Marioware, Rock Band, Mario cart, Wii Play, Play Ground
Wrist extension	CIMT & HABIT	Racing	Wii Play
Finger strength	CIMT	Shooting, guitar	Wii Play, Guitar Hero, Rock Band

Patients can now follow natural body movements associated with various sports and activities. Some refer to the game activity as "Wii-habilitation" [88], because the gestures have similar characteristics to traditional therapy exercises. The interactive nature of the game allows children to use skill sets associated with sports. Players direct the actions of animated athletes on screen making repetitive tasks more goal-oriented. The sensing technology is surprisingly accurate. When comparing center of pressure data from the standard Nintendo Wii balance board (such as WiiFit game) and a laboratory-grade force platform, similar output was found [24].

Children in the CIMT group are required to use their involved UE for games involving just the Wiimote (e.g., tennis, bowling, shooting games, etc.). A second (nunchuk) controller can be connected to the Wiimote for bimanual activities for children in the bimanual training group. Table 1 shows various clinical goals and example Wii activities and specific games to work on them. This could involve a combination of steering with one hand and shooting with the other, boxing, mimicked running or swimming with the two UEs etc. The Wiimote can be encased in other devices (e.g., a steering wheel which would require supination movements of the UEs, or a crossbow, requiring stabilization and manipulation). Additional devices can be attached (e.g., musical instruments) to elicit other movements.

11.1. Limitations of commercially available applications

The low cost of the commercial game console interests many as a potential training device for rehabilitation beyond the clinic [27]. This sounds promising, but there are some negative implications. Along with the usual concerns of motion sickness, seizures, and blackouts triggered by light flashes in video displays, the lack of professional guidance can raise concerns. If children are unsupervised, too much excessive motion from excitement may cause motion injuries. For example, the Wii Sports game can involve rapid motion leading to wrist injury and muscle strains [9,32]. Referring to any activity afforded by an input device (e.g., Wii remote) as "rehabilitation" may be misguided since rehabilitation tasks need to meet specific criterias. Mapping the choice of method to a precise motor action requires expertise. Using commercial game consoles require therapists to be creative in how games are used to address target movement impairments. One concern is that non-professionals may try to replace training with gaming activity, rather than use gaming to assist current rehabilitation tasks.

Our experience has been that the Wii is particularly good for promoting proximal movements and dissociating elbow and shoulder movement, UE strength, accuracy, trunk control during UE motion, increase core stability, increase range of motion and eye-hand coordination. But it is less effective at promoting distal/manipulative behaviors. The interventionist must take into account balance abilities, cognitive function and motor abilities of the child. The environment must be free of obstacles (or other children) to prevent injuries. Strength can be promoted by adding wrist weights as appropriate. Balance can be challenged by performing activities while seated on a Swiss ball. We generally use active movement-based games as opposed to slower exploratory games which do not require the same intensity of movements per time unit. Paradoxically, since children often already engage in video gaming in the home environment, the games themselves are unlikely rewarding, specific or intense enough to elicit movement changes and improvement in movement ability. Thus therapists must be extremely creative about how the games are used to target movement impairments.

Given this and the fact that such gaming systems were not designed specifically for rehabilitation, we view gaming as complimentary, but not as a replacement, to salient task-oriented activities in the real world.

12. Conclusions

Task-oriented training approaches offer the potential to take advantage of brain plasticity and residual capabilities to improve motor performance in children with CP. This approach his consistent with functional training and practicing predefined goals in therapeutic environments [1,12,68,74], which are increasingly showing efficacy. The results thus far suggest that it is important to put the training goal first, and then choose the appropriate training protocol to meet those goals. This could involve either unimanual protocols such as CIMT or bimanual training such as HABIT. However, practice must be specific, sufficiently intense and increase in complexity and challenge (involve motor learning). It must also be salient to the performer, and for children, this means participation must be fun.

Video gaming is an activity that most children already engage in, and from this perspective, is salient. Commercially based gaming systems can readily be adapted for use in rehab settings to elicit practice of targeted movements that is fun and goal-directed. The challenge in applying gaming activities to physical rehabilitation is the lack of physical/occupational therapists that are knowledgeable in both domains (physical rehabilitation and video game technology). There is a need to effectively map commercial game activities to physical rehabilitation, or administer VR exposure in a safe manner. Current gaming consoles and VR environments are very promising and are powerful tools that can extend the skills of a well-trained physical/occupational therapist.

In the context of intensive treatments such as CIMT and HABIT, it can be used to diversify the activity bank and motivate children to direct their attention toward specific movements. However, they should not be viewed simply as a reward or a break from other real-world activities. Therapists need to be creative about how the games are used to target movement impairments. We view gaming as an important compliment to, not a replacement for, salient task-oriented activities in the real world. As affordable sensor technologies develop and evidence-based research is conducted, we expect video gaming to increasingly be an important part of future rehabilitation efforts.

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