Chapter 9

Virtual Reality in Rehabilitation of Children with Cerebral Palsy

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Additional information is available at the end of the chapter

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1. Introduction

Cerebral Palsy (CP) is a continuous but non-progressive motion/posture, motor function disorder resulting from a lesion in the developing brain primarily damaging the areas responsible for the postural control, affecting 2.1/1000 live births [1, 2]. That is the most common cause of physical disability in the early childhood period and a serious disorder also affecting the family, and the child's education and social life [3]. Recent researches, finding an accepted international definition of CP have been somewhat a challenge, but the proposed prevailing international definition [3-5]. In the last decade, the International Classification of Functioning, Disability and Health "ICF" developed by The World Health Organization constituted a new defining to understand CP and to think about intervention possibilities for clinicians, researchers as well as families [6, 7].

ICF is the transition from an "outcome of disease" classification to a "components of health" classification. This system, which aims to develop a common language and framework among health professionals considering above-mentioned multidisciplinary approach and communication, has rapidly become a focus worldwide. ICF is a system that classifies health and health-related fields. These fields are divided into two parts as the body, and the individual and social perspective: "body functions" and "body structures" form the first group, and the "activity and participation" field forms the second group. In recent literature, assessment tools, intervention techniques and researches outcomes are investigated in according to the dimensions (ICF): body function (e.g. physiological, psychological); structures (e.g. anatomical); activities (tasks); and participation (life roles). Thus, this "bio psychosocial" model of disability encourages a more holistic approach to rehabilitation (Figure I) [6]. "ICF Classification" for children with CP is a beneficial system that can be used in the formulation of problems in

different areas, to build a bridge between professionals themselves and with the family. ICF can help the child's physiotherapist in deciding about the process and in determining special functional objectives [4]. ICF-CY (Child and Youth version: ICF-CY) is the updated version that specially attended to aspects of learning, behavior and development for use in children and adolescents from 2007 [8].

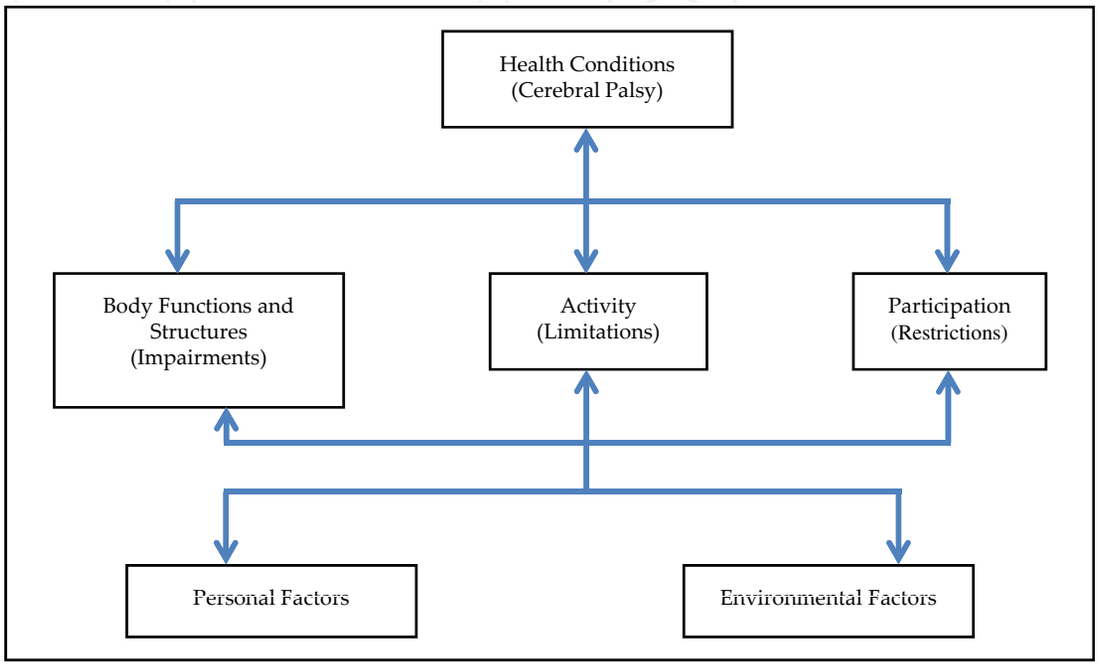

Figure 1. ICF bio psychosocial model

When viewed from ICF aspect, CP affect on a child's "functioning" (including of body structures [e.g. limbs, eyes], body functions [e.g. sensory, neuromusculoskeletal and mental functions], activities [e.g. walking, writing, learning] and participation [e.g. playing sport, going to concert] and besides that personal [e.g. motivation, anxiety, toleration, age, gender] and environmental factors [e.g. architectural accessibility, policies, physical accessibility of cultural, athletic or recreational centers] influence independence of CP children in their daily life and leisure activities. Moreover, CP may cause "disabilities", such as impairment, activity limitations and participation restrictions [9, 10]. Beckung et al. have investigated activity limitations and participation restrictions with gross and fine motor functions under the mobility, education and social relationship sub-headings proposed by ICF in children with CP. They indicated that effect of a child's impairment or activity limitation on participation might vary depending on environmental factors [11].

At first, most clinicians and researchers thought that CP is primarily a movement disorder but recently it is an umbrella term used to define a group of permanent conditions, indicating that there is heterogeneity in these conditions such as visual, cognition, perceptual and/or behavior, sensation problems and learning disabilities [12]. Neural disorders such as spasticity, co activation of agonist-antagonist muscles, muscle weakness, lack of selective motor control and

restriction of normal joint movement and knee pain affect gross and fine motor functions in CP [9]. Many children with CP may never attain the abilities of their peers who are typically developing or lose some of them with growing [13]. There are many potential problems children with CP and these influence complexity of therapy planning and execution.

In CP treatment, the rehabilitation modalities are considerably wide including conventional interventions and new rehabilitation techniques. Medical and surgical approaches, physiotherapy, ergotherapy, speech therapy, orthoses and other supportive devices, recreational activities, school and education adaptation and psychological support can be considered in these modalities. The main aims of the rehabilitation in CP are to help the child achieve the highest possible physical, cognitive, psychological and social independence level within his/her physiological and anatomical deficiencies and environmental limitation, to reduce the effects of physical disorder to minimum, to improve the independence in daily life activities and social life, to increase the life quality of the child and thus support the quality of parents and siblings life [14].

Physiotherapy modalities in CP aim not only to improve the movement ability of the child, but also to reach normal level in all development stages. Rehabilitation in the children with CP depends on the clinical type, accompanying disorders, chronological age and the socioeconomic factors. Especially visual, hearing, cognitive disorders, attacks, learning disorder, emotional state problems are among the problems that affect the success of the rehabilitation [15]. Thus, a multidisciplinary team is required in the treatment of these heterogeneous groups of problems. This team must include specialist physicians (pediatricians, pediatric neurologist, orthopedist, neurosurgeon, neonatologist, child psychiatrist, dentist and all related physicians), physiotherapist, ergotherapist, psychologist, child development specialist, dietitian, social service expert and caregivers for the child.

The children with CP are referred routinely to physiotherapy in the very early ages. But the main question is whether there is a scientific evidence to confirm the use of physiotherapy so often. Recently the most debated subject is if the treatment modalities performed in CP have an effect on the neurological process. The studies and clinical literature about the effects and density of the treatment are still unclear with lack of evidence and discussions on the field are predicted to continue in the future. Over the past 20 years, the early interventions for the children with disabilities have focused on evidence-based practice including the child and family centered approach. Therefore the examination of the efficiency of these applications is of great importance for clinicians and researchers [16]. It is accepted that physiotherapy applications play an important role in the CP rehabilitation, but which method, how much intensity and how long should be applied? These questions cannot be answered easily. The most criticism of denominated therapy modalities is that the lack of scientific baseline and evidence of activity. The evidences that support any efficiency of modality or that indicate the superiority of any other modality, are limited, and physiotherapists have been increasingly searching to evidence- based applications. To evaluate the efficiency of the therapy modality, which is performed for any motor problem or physical deficiency, is difficult due to several reasons. The main reason is the absence of standardized specific treatment. In other words there is no dosage application under the specific, stable procedures in many cases. Researches

regarding interventions in CP indicate that 30%-40% of interventions have no reported evidence-based, other 20% of interventions informed ineffective, unnecessary or harmful. The current review is showed botulinum toxin (BoNT), selective dorsal rhizotomy, casting, constraint-induced movement therapy, bimanual training, context-focused therapy, goal-directed treatment, and occupational therapy following BoNT are effective interventions for body structures and functions level or the activity levels on the ICF but unfortunately, there were no evidence-based effective interventions for improving participation, environment or personal factors levels of the ICF. A high incidence of CP intervention studies, approximately 70% are low level evidence-based and required to increase their research quality to prove effectiveness of treatment. These modalities are assistive technologies, animal assisted therapy, strengthening, hippotherapy, hydrotherapy, early intervention, cognitive behavior therapy, communication training, orthoses, oral-motor therapy, play therapy, stretching, treadmill training and parent training. In addition, ineffective interventions are determined neurodevelopmental therapy (NDT), craniosacral therapy, hyperbaric oxygen, hip bracing and sensory integration [10]. There is a contradiction for NDT that is commonly used interventions all over the world. Todays' Bobath therapists focus on motor learning principles, family-centered practice, orthoses, BoNT, assistive devices, functional training, constraint movement treatment, strengthening and bimanual treatment within right body alignment and aim to improve posture. NDT may influence functional motor gains (low-evidence) but there are great requirement rigorous future researches to demonstrate effectiveness of NDT.

Also, physiotherapist focuses on the functional movement and gross motor skills in the treatment of motor disorder of the child with CP. Positioning, sitting, gait with or without orthoses, the use of wheelchair, transfers are some of the areas on which the physiotherapist work. Physiotherapist plans the physiotherapy and home programs, provides the school arrangements, and makes decision about orthoses and supportive devices. Physiotherapists teach the families how to feed, bath, cloth and hold their children during daily living activities; and also give advices about assistive devices [17]. Thus, the physiotherapists aim to maximize the child's performance by focusing the needs of the child [16].

The frequency of physiotherapy is not definitive, but some families and professionals think that physiotherapy is more useful when its frequency is increased. Recently, physiotherapist focus to solve the needs of the family and child and decide which therapy and frequency should be applied to the child [16]. Dosage or duration of treatment can be arranged coherently, but the procedures are based on the skill levels and specific aims of physiotherapists, therefore they can be varied. Even if the arrangements of treatment can be standardized (a condition of the treatment), the family of the child can never be standardized (another condition of treatment). All problems that accompany a research included low incidence and high heterogeneous condition, become complex with the process of growth and maturation.

All in all for the physiotherapists it is important to separate the evidence-based applications and clinical applications [10]. Therapists try to find a balance between the attractive and effective activities in the treatment process of children with CP [18]. CP is a heterogeneous group, so more general principles are used for treatment and rehabilitation [19]. During the last 10 years, popularity of performance based or "top-down" approaches based on motor

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learning theory in which interventions focus directly specific task training in activities of interest and are not concerned with underlying impairments body structures and function, are gradually increasing such as goal directed therapy, constraint induced movement therapy [10]. While technologies come into our life, physiotherapy approaches changed and developed. Treatment of motor impairments with new complementary technologies such as robot-assisted therapy, locomotor therapy or computer based rehabilitation systems would improve motor development in children with CP, especially intense growth and adolescent period also after the multilevel surgical intervention, that effect muscle strength and body alignment. The success of the rehabilitation process depends on several factors: the intensity of therapy, repetition, and goal-directed or task-oriented therapy program are considered essential in achieving motor outcomes. During the past decades new technologies have been developed to improve sensory motor learning in children with CP. Motivation and active participation of children in intervention program play a fundamental role in the sensory-motor learning process and these are the key factors of successful outcomes [20]. Over the last three decades, there has been an increase in the number of individuals engaging in interactive computer plays [21]. Therefore, current studies focus on Virtual Reality (VR). VR as an intervention for sensory motor rehabilitation is promising tool in order to improve lower and upper limb function and also postural control in children with CP.

Virtual reality is a technology that provides a sense of presence in a real environment with the help of 3D pictures and animations formed in a computer environment and enable the person to interact with the objects in that environment. In other words, VR described as an improved form of human-computer interaction that allows the user to be part of and interact with a computer-generated environment [22]. A virtual environment (VE) is created by various computer technologies. The key specialty that separates VE from other forms of visual imaging, like video games or television, is real-time interaction. However, the interaction can be achieved in various ways. VE shows virtual or artificially produced sensory information, and allows the user to feel experiences similar to the events and activities in real life [23]. Interactive simulations that enable the participant to create an interaction between body movements and 3D area are therefore constituted [24]. The person sees and feels objects and events similar to those in the real world, can manipulate and move the virtual objects, and can do other things in the virtual environment he/she is in. Thus, "an imaginary presence feeling" occurs in the virtual world. In short, VR is the rebuilding of reality [25]. Some studies named these systems "Interactive computer play-ICP" is defined as any kind of any computer game or VR technology where the individual can interact and play with virtual objects in a computer generated environment. Fehlings et al indicated that there is a significant similarity between terms ICP and VR [26].

The use of VR applications started in the 1950s with a theatre machine called Sensorama. This machine, developed by the cinematographer Morton Heilig, was constructed to address all senses. Sensorama combined projected film, audio, vibration, wind, and odors, all to make the user feel as if they were actually being in the film rather than simply watching it. For example, one experience provided was driving a motorbike on the streets of New York. In addition VR was developed by the USA air and airplane industry during the 2nd World War. The Head

Mounted Display (HAD) that appeared in 1965 has been a milestone for VR applications. Ivan Sutherland developed (HMDs), which allowed users to be immersed inside a virtual environment with computer-generated scenes. To compare to the technology of 21th century both interface and realism were primitive, and the HMD was so heavy it had to be suspended from the ceiling. The potential of VR was recognized by researchers from many different areas and especially military [27]. The following decades VR is growing rapidly both regarding technological advancements and in areas of implementations. In order to accomplish the feeling of a strong presence, various stimulation modalities are provided to the users (audiovisual feedback). Since then VR has been successfully integrated into several areas of medicine and psychology as for example: training and education in surgical procedures; education of medical students; assessment and treatment of mental health problems including phobias and post-traumatic stress disorders; pain management through distraction; and in motor rehabilitation, where examples of explored areas are upper limb rehabilitation in persons with acquired brain injury; fall risk reduction in Parkinson's disease, particularly stroke rehabilitation and in pediatric rehabilitation field [28].

VR use in physiotherapy and rehabilitation has increased significantly in the last 6-7 years. Depending on the characteristics of the software used, VR-based therapies provide significant experiences to the user within the targets of the therapy. VR applications became the spark among new treatment modalities used for individuals with CP as computer technology became intriguing and motivating for children and young people and interest on the subject gradually increased. VR provides an opportunity for active learning, encourages the participant, and ensures motivation. It enables performing difficult movements in a secure environment and objectively shows the behaviors that are a result of these motions. An ever-increasing number of studies report that VR implementation in children with CP positively affects brain reorganization, plasticity, motor capacity, visual perceptive skills, social participation and personal factors [29].

2. Theoretical Base of Virtual Reality therapy

VR therapy includes the basic principles of the motor learning theories [19]. It provides this by enabling the user to continuously see the movements in 3D from the computer screen. VR provides repetitive practical and positive feedback in order to increase the functional independence in daily tasks. Holden et al reported the possibility of learning motor abilities in the virtual environment by individuals with a disorder. Movements learned in VE can be transferred to real life with equivalent motor tasks [30]. The first studies on this subject reported that the VR method was usable, a lot of fun but not successful for treatment. However, VR has been shown to provide motor recovery in the upper extremity in adult stroke rehabilitation [31].

According to the motor control and motor learning theories, motivation, repetition, and purposeful and special target-directed training should be used in the treatment of children with CP. The addition of games and social activities during rehabilitation is also important for

ensuring the development of the child. A good treatment should enable the therapy to be transferred to daily living activities and tasks. Treatment techniques based on motor learning theories use intensive practice of functional activities and show good results [32].

Active participation instead of passive practice is recommended for motor learning and cortical reorganization. Passive exercises have been shown not to enable maximum improvement in the affected upper extremity in patients with stroke. It is also necessary to provide and strengthen new motor skills, provide functional and duty- focused practices and increase motivation for re-learning and recovery after a stroke. Although motor learning is quite different in children with CP compared to patients with stroke and spinal cord injury, focusing on the activity and task is one of the most important aspects of the treatment in children [19, 33].

One of the major purposes of rehabilitation in child and adult patients is to restore the basic abilities. Recovery after neural damage usually depends on various factors such as the nature and amount of the rehabilitation. Conventional rehabilitation programs are shorter and less intensive to ensure optimal therapeutic results. They cannot adequately increase the motivation of the patient or support activity participation. Many studies have shown that the motivation of patients plays a critical role in treatment results. The virtual environment can also provide more intriguing and competitive conditions, by increasing the motivation of the patient and ensuring active participation, so that less time is used for regaining motor skills [34].

The results of the use of VR as a treatment approach in adults and children are promising. There are many factors lying behind the use of VR in rehabilitation; it provides a variety of environments, and an environment that is similar to the natural one can be designed to test performance and provide independent training. Designed scenarios can be used to train functional behavior in real life and improve functional performance [29]. The "mirror neuron system" is considered to be a mediator for relearning in cases of disturbed cortico-motor function [35]. The mirror neurons activate not only when performing a motor activity but also when observing, imagining, or listening to the same motor activity [7]. There are many important views on the development and structure of the mirror neuron system in children [36]. The development of this system in children supports motor learning and social function in daily life. Cortical reorganization implementations have been developed with mirror neuron system features. The results revealed the usefulness of transferring mirror neuron information to the treatment in the clinic. The premotor cortex has critical importance in motor learning and motor control. This cortex is divided into dorsal and ventral parts. The ventral premotor cortex (PMv), hand area of the primary motor cortex, anterior intraparietal area, and the supplementary motor area are associated with Brodmann 3, 1, 2. The dorsal premotor cortex (PMd) has more projection than PMv with the lateral intraparietal area, primary motor cortex, supplementary motor area, cingulate gyrus and Brodmann 5 [37, 38]. (Figure II). The position of movement towards the target has been coded in PMd cells. PMd neurons are active in the preparation phase of the movement and play a critical role in motor planning. They are responsible for planning and learning the movement and the constitution of the postural responses for the future. The ventral premotor cortex (PMv) is important in the sensorimotor processing of movement and is considered to be associated with the cognitive aspect of target-

directed activities. It is a part of the mirror neuron mechanism. Brief pictures for motor movements are coded with two-way activation of PMv mirror neurons during the implementation and observation of the movement. We are therefore able to understand the movements of others in advance. Learning a motor skill is a cognitive and motor process. Motor learning is briefly gaining the movement skills for a complex target with practice. PMd is active during the early phase of motor learning, and is associated with spatial mapping while PMv is critical for motor learning in the sensorimotor transfer of vision-based motions. PMv neurons are involved in monitoring performance and deciding on the choice of motion in practical terms. The mirror neurons inside PMv play an important role in observational and mimic learning [7, 39].

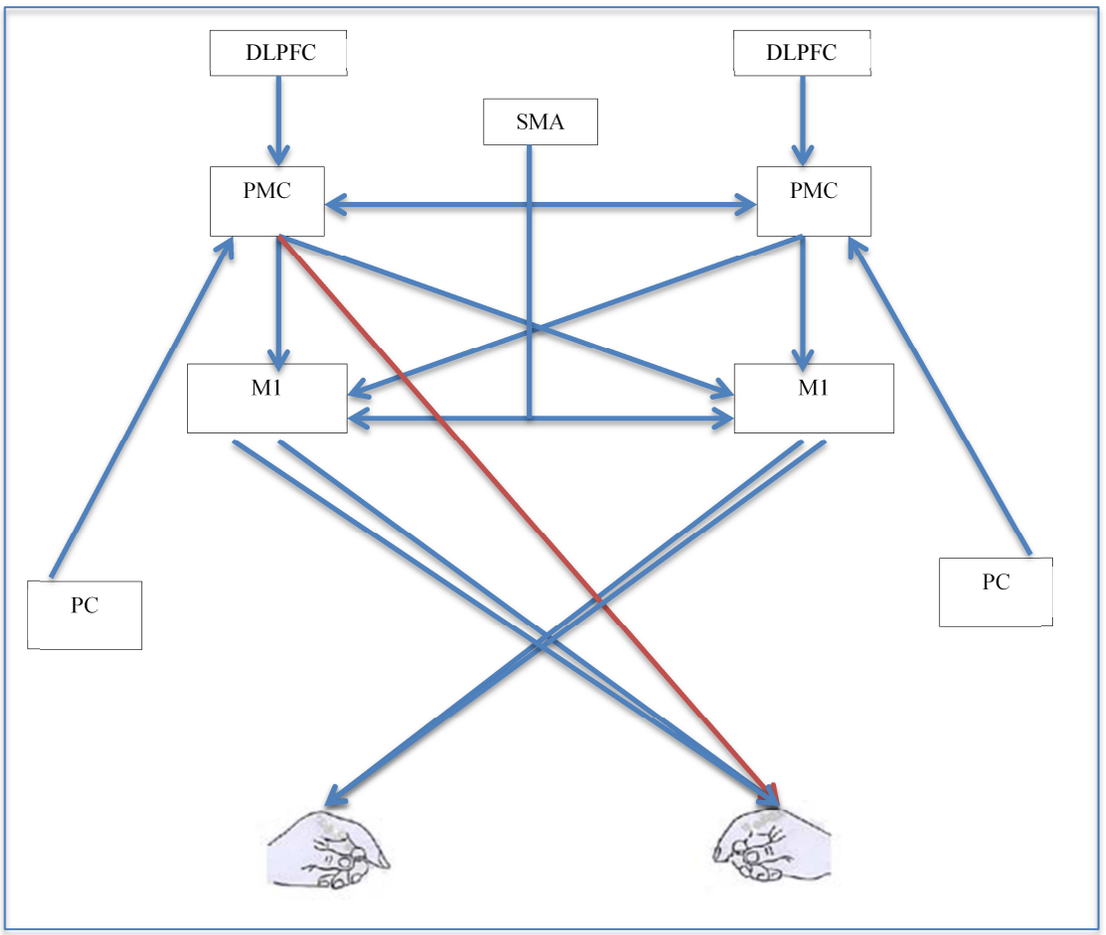

Figure 2. Kantak et al with kind permission "Premotor cortex (PMC) forms a part of the neural network involved in integration of sensory and cognitive information into goal-directed actions. PMC receives sensory information from the parietal cortex (PC), cognitive information from the dorsolateral prefrontal cortex (DLPFC) and supplementary motor cortex (SMA), and projects to the primary motor cortex (M1). In addition, it also has direct projections to the spinal cord via the corticospinal tract. These connections within the neural networks are plastic and are modified in response to injury, learning, and training/therapy [7].

The mirror neuron mechanism constitutes a physiological basis for motor memory and motor learning. The mirror neurons map the observed target activity in a pictorial and

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kinematic manner and activate with the mobility recognition mechanism. It is believed that the primary motor cortex is facilitated with VR implementations [7]. In conclusion, activation of the mirror neuron system stimulates cortical reorganization and contributes to functional improvement [38].

3. The benefits of using Virtual Reality in rehabilitation

The first results in the literature showed that VR was a robust treatment method that was functional, target-directed and motivating [30, 40]. Studies, especially in the field of pediatric rehabilitation, have taken the various aspects into account (such as development of life skills, mobility, cognitive abilities, entertainment, motivation). VR provides specific and intensive treatment for children. However, evidence supporting VR implementation for the rehabilitation of children with neurological disorders is still limited [28, 31].

New technologies like VR play an important role in functional training and performance. VR allows intensive and motivational training. It enables the use of many interactive environments and multiple sensory feedbacks [41]. The use of this technology in disabled individuals ensures communication with others, improves social relations, and increases independence. VR meets important criteria for motor learning and motor control. VR applications also enable the therapist to train the child at home [30]. High levels of motivation, participation, and cooperation are essential components of a game system. These characteristics of the training support behavioral changes and neural plasticity. In conclusion, multi-sensory feedback explains the improvement in learning and performance. VR implementation in children with CP positively affects brain reorganization, plasticity, motor capacity, visual perceptive skills, social participation and personal factors (Table I) [42, 43].

The benefits of using Virtual Reality in rehabilitation
Increases motivation
Demonstrate target-directed functions more realistically
Provide an experience for the child according to his/her own motor learning capacity
Support motor learning
Support cortical reorganization
Provide interactive treatment

Table 1. The benefits of using Virtual Reality in rehabilitation

4. Virtual Reality systems used in pediatric rehabilitation

The popularity of computer technologies has increased between both children and adults. In addition video games are an important part of leisure activities for the young. Actually, one

of every 4 children in the USA now has his/her own video game console at home. In last 10 years, active video game consoles give an opportunity to transform sedentary screen time into a period of physical activity. Examples are Sony PlayStation, Nintendo Wii, etc. [21]. Active video consoles based on VR concept and allow interactive physical activity. Nowadays, the computers systems focus on touch technology that are rapidly improved and become significant part of our personal, social and occupational life. Touch technology is frequently used in most area such as airports, cell phones, tablets due to easy manipulation of touch interface, flexibility and convenience [44]. The numbers of touch screen devices are gradually increased from 665 million in 2011 to 1350 million by 2014 [45]. According to our clinical experience many therapist use these touch technologies and active video consoles in CP rehabilitation to motivate children and take advantage of variable applications. Thus, children and young people with disabled or not are now more familiar with such technologies. They can be used as free-time activity and a socializing method.

VR is used in rehabilitation for the development of an interactive game environment so that the special aims of the treatment can be achieved. The first purpose of VR as a treatment modality is to develop the confidence and adequacy in motor-based and game-based activities that are impossible for the patient to accomplish in the real world [29, 31].

There are several methods where the users are in interaction with virtual reality technologies. The phrase 'interactive computer game' has been created to understand these differences [23]. An interactive computer game is any kind of computer game using virtual reality where the child can play and interact with virtual objects on the computer or the created environment. There are different types of VR systems that separate according to immersion degree and how the users interact with the system [25].

The virtual environment can be divided into 2 subgroups;

1 Immersion VR; the virtual environment is shown with a screen mounted on the head. Immersion means how much the user feels virtual environment like real. All immersive systems, users wear a head mounted display that brings them into a 3D virtual environment. Movement through VE is controlled by head movement.

2 Desktop VR; the designed images are seen on the computer screen, or on the TV screen together with the voice of an external speaker. The other VR systems the users feel the VE in a 2 dimensional flat screen and they focus on total body movement that controlled a mouse, joystick, keyboard [22].

Tactile feedback can be provided by a feedback glove, and force feedback by providing resistance with the joystick in the virtual environment (VE). Systems connected to the internet (tele-rehabilitation) have the potential to reach out to children who are in distant areas where healthcare services are limited [30]. (Figure III-IV)

Those that were not specially designed for use in rehabilitation

The cost of simple VR game systems like Nintendo Wii is low and they are available in the physiotherapy departments of many third world countries. The use of Nintendo Wii may be

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beneficial in the rehabilitation process for physiotherapists who work in an area with limited resources [18]. Current virtual reality systems like Interactive Rehabilitation Exercise System (IREX) are expensive and inaccessible for the majority of the population. Therefore, the use of mainstream game consoles for treatment has become popular [46].

Figure 3. VR application with The Rutgers Ankle CP. Copyright Rutgers University Tele-Rehabilitation Institute and Washington University in St. Louis. Reprinted by permission.

These products (Nintendo Wii, Wii sport games, Wii fit) use motion-sensing technology. The technology perceives speed and orientation with the manual remote control. The player mimics the physical movements of games such as baseball and skiing with the remote control. A pressure-sensitive balance board can be used. Physical activities in yoga and similar balance games can be mimicked [47, 48]. Sony Eye-Toy is another video game and used with PlayStation 2. This system contains a small camera and perceives the body of the person and then transfers the appearance to the imaginary system [23]. Dance Dance Revolution (DDR) can be used with Nintendo, PlayStation and Xbox game. It contains a pressure-sensitive mat. It follows dance movements and transfers them to a virtual environment with e-dimensions [47].

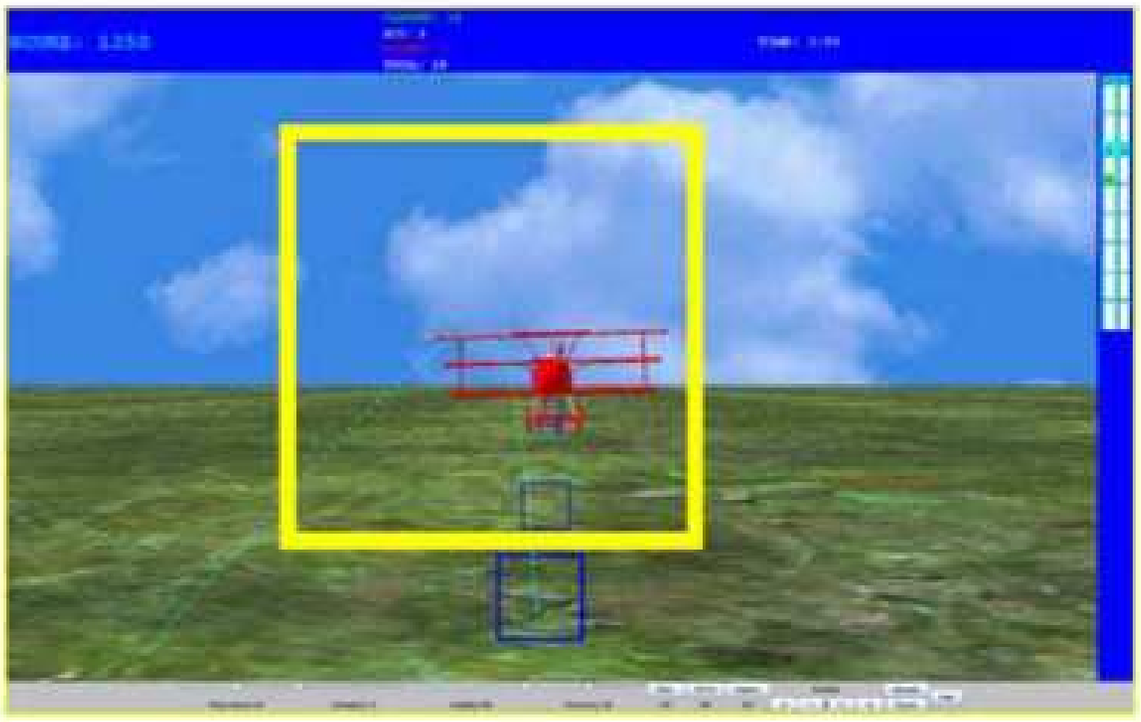

Figure 4. The Rutgers Ankle CP: Game starting screens. Copyright Rutgers University Tele-Rehabilitation Institute and Washington University in St. Louis. Reprinted by permission.

5. Virtual reality systems designed for rehabilitation

Marketed games are not appropriate for patients with "severe spasticity". Pressing on a button in an extremely difficult way or holding the remote control for a long time can be required during the game. The failure of patients to finish the game is due to games being designed for young healthy adults and this decreases self-respect while leading to depression. Games that can automatically adapt to the decreased functions of each patient and that can provide the repetition necessary for neural change are necessary for amusing game-based hand therapy in children with CP who have severe spasticity [49]. Examples are Sony PlayStation 3-supported sensory glove and the Pediatric Intensive Therapy System (PITS); contains a sensory glove and games appropriate for rehabilitation. PITS has been developed for children with upper extremity dysfunction and decreases the dependence of patients, increases self-sufficiency in exercise control and decreases the therapy cost [50]. The Interactive Rehabilitation Exercise System (IREX); uses motion-sensing technology and video capture [46].

6. The advantages and disadvantages of VR systems

Knowing the advantages and disadvantages of the systems is important in determining appropriate virtual reality applications for clinical use and research. Galvin et al gathered and

classified the VR systems used in the field of pediatric rehabilitation in a very detailed and explanatory manner for clinicians and academicians in their review. This is valuable explanation for researchers, clinicians, master and doctorate students to support, help and make easier in choosing VR systems according to their target functions (Table II) [47].

Classification of Virtual Reality Systems for Rehabilitation		
VR systems focused on whole body movement, upper-lower extremities	Upper Extremity	PITS
		PS3 Glove
	Whole Body	Eye/Eye Toy
		IREX
		Wii/Wii Fit
	Lower Extremity	DDR
Cognitive–Motor relationship	Those with cognitive-motor relationship	IREX
		PITS
	Those without cognitive motor relationship	DDR
		Eye/Eye Toy
		Wii/Wii Fit
		PS3 Glove
Those with the ability to focus on movement quality	IREX	
	PITS	
	PS3 Glove	
	Eye/Eye Toy	
	Wii/Wii Fit	
Those without the ability to focus on movement quality	DDR	
Those that require the ability to maintain the straight posture of the body	Standing independently	Wii Fit
		DDR
	Sitting and others	IREX
		PITS
		PS3 Glove
		Eye/Eye Toy
		Wii

Galvin and Levac with kind permission [47].

Table 2. Classification of Virtual Reality Systems for Rehabilitation

7. Virtual Reality studies in rehabilitation

Virtual reality studies are promising for clinical use in pediatric rehabilitation, especially in CP. Parsons et al reported using VR treatment as a rehabilitation approach in children with CP to be more effective than in children with autism and attention deficit [51]. Researches focused on using VR systems in CP interventions, aimed to prove effectiveness of VR on the body structures and functions, activity and participation according to the ICF components. Most of them used applications to reduce impairments of body structures and functions [29]. These researches can be separated subgroups according to their goal as upper extremity, lower extremity, postural control, physical-cardiovascular fitness, and education.

8. Studies focused on upper extremity

All studies aimed to improve function or quality of movement in upper limbs in order to achieve better performance in daily life activities and increased social participation. Researches about this issue are rapidly increasing and then question that "Does VR applications really improve upper limb function?" came up. Accordingly, Galvin et al reviewed 5 studies that used VR to develop upper extremity skills in children with CP. The findings were reported to be limited due to the inconsistencies in result measurements [52]. Also, Wang et al reported that study designs, result measurements, and therapy intensities were heterogeneous and sampling groups small in their review on VR applications and supported the use of VR for upper extremity training in children with CP [53]. However, for CP treatment, it is difficult to demonstrate changes in quality of movement. For instance, Reid et al treated 4 spastic quadriplegia and diplegia patients between the ages of 8 and 12 years. Treatment was implemented for 1.5 hours per week for 8 weeks. They showed that the BOTMP scores increased but the quality of upper extremity movements did not change [31]. In the other study of Reid et al divided 31 children aged 8-12 years as 19 VR subjects and 12 control subjects in their randomized controlled study. Treatment for 1.5 hours per week for 8 weeks was implemented for the children. Canadian Occupational Performance Measurement (COPM) and Quality of *Upper Extremity* Skills Test (QUEST) were used to evaluate the effect of the treatment. While the results of all participants improved after the treatment, no significant functional difference was found between the groups but there was significantly increased social acceptance and motivation in the treatment group [54]. Small sample size or inability of assessment tools to measure quality of movement may induce these results. On the other hand, there are evidence-based studies showed improvement quality of movement. One of those, a study of You et al conducted on children with hemiparetic CP to investigate VR-based cortical reorganization and functional motor development. They treated the child with IREX for 60 minutes 5 times a week for one month. The Bruininks–Oseretsky Test of Motor Proficiency (BOTMP) score was shown to increase from 1 to 5, the Modified Pediatric Motor Activity Log (PMAL) questionnaire from 0 to 3 and the Fugl-Meyer (FMA) score from 39 to 52. The authors reported functional motor skills and amount of use in affected upper extremities and the quality of the motion, active movement control and coordination of upper extremity motor performance

increased. According to the functional magnetic resonance imaging (fMRI) results, the increased abnormal activities in the ipsilateral and contralateral primary sensorimotor cortex before the treatment decreased while the primary motor cortex and primary sensorimotor cortex were found to be more active. The authors showed that internalization of the motor process in target motor behavior is facilitated during visual sensory feedback and VR therapy. This internalization leads to the formation of new motor pathways especially around the sensorimotor cortices (SMC). They demonstrated that VR therapy stimulates neural motor pathways that were not previously used and might develop neuroplasticity. Thus, motor skills of the affected extremity of the child have developed and cortical reorganization was similar to that of a normally developing child after VR application [55]. Similarly, Chen et al investigated the benefit of VR use for reaching activity in 4 children with CP between the ages of 4 and 8. They used the Sony Eye-Toy system. Children were treated for 4 weeks at 2 hours per week. Reach kinematics and PDMS-2 results of the children were found to increase. The quality of reaching was shown to improve after individual training for 4 weeks [56]. Most of the researches showed improvement upper limb functions via VR interventions. Jannink et al included 12 children with CP for upper extremity training with a Sony Eye-Toy in a weakly randomized controlled study. A treatment of 30 minutes was implemented twice a week for 6 weeks between the ages of 7 and 16. Upper extremity functions were evaluated with Melbourne. The results of two children in the treatment group were shown to have increased from 9% to 13%. The authors reported the Eye-Toy to be a motivational education tool that developed upper extremity function in children with CP [57]. Also, home-based treatment approaches are important to integrate effectiveness of VR intervention in daily life and to increase the time of intervention. Huber et al developed a PS3 home hand rehabilitation system for hemiparetic young people with CP and Burdea et al reported pre-treatment hand values of 45% for extension, 70% for flexion and post-treatment values of 70% and 90% after using this system for treatment for 2 months. Grip strength increased by 50% and the Jebsen hand function test results increased. The bone mineral density also increased [49]. Then again, Winkels et al included 15 children with CP between the age of 6 and 15 in the study where they aimed to evaluate the effect of upper extremity function training in children with CP by using Wii games. Children at level I and II according to the manual ability classification system (MACS) were included in the study. The children were evaluated with the Melbourne Assessment of Upper Limb Function and ABILHAND-Kids before and after the treatment. A marked increase was found in the performance of daily living activities. Those who received low scores in the Melbourne evaluation at the beginning showed great improvement in upper extremity function. It has been said that treatment with games is more suitable for children with a more severe disorder. Health professionals and children have been satisfied with the Wii boxing and tennis game [41]. As result, these studies proved VR systems are motivational, familiar and useful for children with CP and can be used for improving upper limb function on the other hand, participants were included, had mild level of MACS or gross motor function classification system (GMFCS), future researches should investigate benefits of VR applications in moderately and severely affected children with CP.

9. Studies focused on lower extremity

The goal of studies associated with lower extremity generally is to enhance walking ability or strength. Another current review, Meyer-Heim et al focused on the treatment of motor impairments with new complementary technologies such as robot-assisted and computer-based rehabilitation systems. Previously, robot-assisted gait training (RAGT) was developed for adults and researched demonstrated its functional benefits such as increased gait velocity, improve balance, reduction of muscular hypertonia and gait endurance. RAGT is based on neuroplasticity of central nervous system within spinal cord to stimulate a basic locomotor pattern via central pattern generators [5]. Mutlu et al, declared partial weight bearing treadmill training can improve walking capacity in children with CP via motor learning [58]. Besides that, a pediatric model of the Locomat designed for RAGT of children starting from age 5 years old due to beneficial outcomes in adults [59]. But one of the limitations of conventional locomotor training is that walking on a treadmill prevents optic flow. Optic flow is important for arrange gait speed and stride length during walking, which visual motion sensed by the eyes as the body moves through the environment. For that reason, combination between VE and treadmill training provide the optic flow of forward motion and may improve walking patterns and also increase motivation and immersion. Integrated virtual environment rehabilitation treatment gained visual and proprioceptive feedback that are necessary for gait training. Because movement patterns can be modified using visual, auditory and proprioceptive feedback. In addition, it is essential to match proprioceptive feedback from the limbs [60]. Other limitation is that walking monotonously for 30-45 min during Locomat or treadmill can be boring for children because motivation is essential for rehabilitation process. Thus, some pediatric rehabilitation centers play music during the treatment [57]. For this reason, recent studies focused on combination with VR system and RAGT. Brütsch et al investigated the effect of VR and Locomat and created a virtual football scenario for the patients. The therapy of 10 children with a neurological gait disorder and 8 healthy children was conducted with the Locomat alone, with therapist support, with VR, and with VR and the therapist together. Results were obtained in the posture and swing phase from the knee and hip joints. No difference was found between VR and a therapist in cases with a neurological walking disorder. Walking with any motor support in children, whether healthy or with a neurological disorder, significantly increased motor results compared to walking without any motivational support. In other words, active participation increased with the verbal support of the therapist, with VR, or with the support of VR and the therapist at the same time. The VR and therapist combination was found to be more effective. VR games provide the necessary motivation for gait training in children. These studies showed that electromyography activity output was significantly higher during task with VR and physiotherapist motivation than during normal walking conditions when walking on the Locomat [34] (Figure V).

Last 20 years, interventions focused on strength training in CP rehabilitation due to understanding important of muscle weakness. In children with CP, muscle weakness influence negatively daily life activities and social participation and decreased functional capacity [61]. Chen et al identified that cycling is an applicable, effective and easy approach for improving muscle strength and developed home-based virtual cycling training (hVCT) program. They included 27 children with CP with GMFCS levels I-II at age of 6-12 years. Children with CP

Figure 5. Examples of Pediatric Locomat virtual reality games. This game has been developed in a close collaboration among the Rehabilitation centre Affoltern, the ETH Zurich and the University of the Arts Zurich. (Color version of the figure is available online.) [5]

performed hVCT program 40 min/day 3 times per week for 12 weeks, that consisted of a 5 min warm-up exercise, 20 repetition of sitting to standing movements, cycling 20 min and a cool-down exercise for 5 min. They assessed gross motor function with BOTMP and muscle strength with isokinetic dynamometer. The results showed significant effect on muscle strength at post treatment. The hVCT group had greater peak torque of knee extensor and flexor at 60^0/s and 120^0/s angular velocities than control group. Changing in strength indices of knee extensor and knee flexor at 60^0/s post treatment were 19-41% in the hVCT group while those were -2 to 1 % in the control group. Also, at 120^0/s at post treatment were 30-36% in hVCT group while -6 to -19% in control group. They suggested that these findings might be lead clinicians to improve muscle strength more effectively [62]. Bryanton et al investigated ankle dorsiflexion kinematics in observational studies they conducted on 10 children with CP and 6 healthy children. The difficulty in voluntary muscle contradiction results in weak selective motor control in children with CP. Children with CP completed their selective motor control exercises with the VR exercise system and conventional exercises. Ankle movements were recorded with the electro goniometer. VR has been shown to provide more repetition than conventional exercises. The joint range of motion and duration of holding in a stretched position were found to be higher after VR exercises. They proved VR use increased compliance with exercise and its usefulness [63]. Burdea et al investigated ankle strength, motor control, gait, function and quality of life development in children with CP while playing VR games in their study. Plantar flexion strength of the children increased 0.15 Nm/kg and the quality of life increased by 2.8% according to the Pediatric Quality of Life Inventory (PedsQL). 400 repetitions were performed for each ankle with the Rutgers Ankle CP system in a game session [64]. Therefore, clinicians can be used VR systems to increase lower extremity strength in children with CP.

10. Studies focused on postural control

Postural and balance control is one of the key factors that affect performance of most functional skills such as walking and reaching. When children with CP have poor postural control, they may fall in walking or may not regulate the velocity of the reaching arm or to initial pelvis

position. The main reasons of dysfunctional postural control are enhanced antagonistic co-activation, reduced capacity to modulate the degree of postural muscle contraction to the specifics of the situation [65]. In last decade, some interventions focused on impaired postural control and balance in children with CP to improve daily life activities [66]. However, there are few evidence-based studies showed effect of VR intervention on postural muscle activity. One of them is a case report by Deutch et al. which is the first study conducted with Wii. A 13-year-old spastic diplegic child was provided VR treatment with the Wii game console for 4 weeks at 11 sessions of 60-90 minutes. They showed that the visual perception process, postural control and functional mobility had increased. They emphasized that stretching behaviors developed with cortical reorganization in the rehabilitation of the upper extremity movements with VR [48]. In another study, Gordon et al included 6 patients between the ages of 6 and 12 years in treatment with Wii twice a week for 6 weeks. Total Gross Motor Function Measure (GMFM) score changed by 7%. The biggest change was seen in the sitting section (12%). The smallest change was seen in the turning section (2%). Two of them used balance assessments to demonstrate differences in postural control [18]. Sharan et al included 16 children (8 study - 8 control) in treatment 3 days a week for 3 weeks with Nintendo Wii sports in a study where they investigated the effect of VR application after surgery in children with CP. An increase was seen after the treatment with PBS. While VR had an important effect on the development of balance, no difference was shown between the control group regarding manual skills. The investigators proved that Wii-Fit use developed balance in the child and balance training decreased the swing of the children with this study [24]. Additionally, Brien et al investigated the functional balance and mobility of adolescents with CP level I according to Gross Motor Function Classification System (GMFCS) after intensive short-term VR application. Four children with CP between the ages of 13 and 18 were treated for 90 minutes per day for 5 days with IREX. Timed Up and Down Stairs (TUDS), 6-Minute Walk Test (6MWT) and Community Balance and Mobility Scale (CB&M) and GMFM E were evaluated. Functional balance and mobility were shown to develop with short-term, intensive VR implementation. The improvement was found to be significant with CB&M and 6MWT in the follow-up period. The development in CB&M is reported to be associated with the development in coordination, time and speed necessary for ambulatory performance of complex motor skills and especially within the society, and this effect was preserved for at least 1 month. The walking endurance necessary for daily life and social participation was proven to be increased [67]. Walking is also influenced of active control of pelvis and trunk. Balance perturbation responses in healthy individuals are formed with the simultaneous contradiction of the neck, body and hip muscles and are seen even before the activation of muscles. Distortion of proprioception in the core environment (body and pelvis) and decreased strength has been found to be associated especially with increased injury risk to the knee in prospective studies. Good control of core movement is therefore a prerequisite for better use of the legs. The interaction between the body and the pelvis is necessary for good control and performance of daily living activities. This interaction during walking depends on the walking speed. While the pelvis and body interact as when the body is standing in the transverse plane at slow speed, the interaction becomes that seen in the swing phase as the rate increases. The protraction of the pelvis together with the retraction of the body in the swing phase increases the step length of the leg.

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Thus, the walk productivity improves. One of the primary problems in CP is the decrease in selective motor control. Poor selective motor control of the pelvis and body distorts walking and negatively affects daily living activities VR training leads to decreased combination of body and pelvis and increased selective control. Co-contraction and combination decreases with increase of selective control of the muscles in the body and pelvis region, while selective pelvis control increases and pelvis rotation-body rotation is facilitated. Co-contraction is the simultaneous contraction of the agonist and antagonist muscle and is used to prevent errors and increase stability when unaccustomed tasks are being performed. The co-contraction level decreases with increased practice [68, 69]. Due to these reasons, Barton et al treated a child with spastic CP 2 times a week for 30 minutes, for 6 weeks. The combination of pelvis and body increased after the treatment [70].

11. Studies focused on physical and cardiovascular fitness

Physical activity consists of body movements performed by using the skeletal muscles and results in spending energy. According to ICF, activity is divided into 2 areas as performance and capacity. Physical activity is made up of the activities the individual undertakes in regular daily life. Capacity is how much people can achieve, such as walking distance [6]. Increasing spend time on watching television, playing electronic games and computers, are generally associated with decreased physical activity and obesity [71]. On the other hand, the children and adolescents active video games are considered interesting alternatives to passive games. There is gradually increasing evidence that internet-based applications and active games can increase physical activity in healthy children [72]. Physical activity and fitness is reduced in children with CP than their typically developing peers and also spend most of their time with sedentary activities, facing a screen [73]. Examples are watching television and playing video games. For this reasons the risk factors to develop obesity, osteoporosis, diabetes, CVS disease or musculoskeletal pain are increased. There is new evidence indicating that VR implementation and the use of motion interactive games increases physical activity in children with CP. Mitchell et al investigated the effects of VR application in children with CP on physical activity. VR implementations are more intense than one-to-one training. For example, "move it to improve it- (Mitii)" provides a total of 70 hours of therapy. Therefore, these systems may provide an increase in physical activity. Physical activity capacity increased with Wii Sports and Mitii and physical activity performance increased with Eye-Toy 2. Functional strength also increased with Mitii training. A few intervention studies investigated effects on physical activity in home use and/or long-term use of active video games. These researches reported that active games could improve physical activity in a moderate level and reduce sedentary screen time. Home based interventions have ranged from 10-28 weeks in duration so the effects of long term use of active games are uncertain. Several studies indicated playtime was reduced during the intervention [74].

In recent review, Fehlings et al pointed that effect of VR on cardiovascular fitness (CVI) in children with CP. For active video games, it's necessary to appropriate physical activity. Active video games have great potential to promote increased physical activity and enhanced CVI

fitness for children with CP [26]. Hurkmans et al investigated effects on energy expenditure (EE) among adults with CP when playing Wii sports. Several researches compared EE measured with indirect calorimetry or by an activity monitor during play of different motion interactive video games to EE during other activities of various physical exertions [75]. Generally activity levels compare with metabolic equivalent units (MET). MET is a physiological concept expressing the energy cost of physical activities and is determined as the ratio of metabolic rate during a specific physical activity to a reference rate of the metabolic rate at complete rest. Therefore 1 MET corresponds to the metabolic rate while at complete rest and 2 METs represent a doubling of the energy consumption. A common grading of physical activity according to METs is: *sedentary* (<3METs); *moderate* (3-6 METs); *vigorous* (6-9 METs); and *very vigorous* (>9 METs). Playing motion interactive games found to increase EE to light or moderate levels around 3 METs, same as brisk walking, skipping, jogging or stair climbing. Sustained vigorous activity above 6 METs is generally not obtained during play. Energy expenditure during play depends on engagement and type of game played. Games that playing on upper body movements compared to games with playing lower EE and higher values are achieved when all body movements are achieved [76]. As result studies demonstrated that active video games generates higher EE compared to rest and sedentary screen time activities but not as high EE values as performing the corresponding real activity in itself.

12. Studies focused on other conditions associated with cerebral palsy

Most of children with CP suffer from several comorbidities in addition to motor handicap such as behavioral, cognitive, and learning disabilities, further impeding their overall functional capacity. Approximately 40 percent of them have learning disabilities and common behavioral symptoms in high-functioning children with cerebral palsy are attention deficits and impulsivity, especially premature birth compatible with the diagnosis of attention-deficit hyperactivity disorder (ADHD). ADHD is one of the major causes of behavioral, friendship and school problems [77]. Pollak et al investigated effects of VR intervention on children with ADHD and produced virtual reality schoolroom environment to motivate children, to support active participation, to evaluate attention and motor behaviors in challenging. Their VR classroom designed according to Rizzo et al Digital Media Works and has head mounted display and gives visual-auditory stimuli with in the VE. In experimental group had 20 boys with ADHD, the control group consisted of 17 boys without ADHD. They assessed with Test of Variables of Attention (TOVA) and virtual reality continuous performance tasks (VR-CPT). According to VR-CPT findings, children with ADHD had slower reaction time, higher variability in RT is more errors of omission and commission than control group. They demonstrated VE provide test and training situations that are ecologically valid, motivating and dynamic. These findings consistent with literature that VR-CPT is a user-friendly method for children with ADHD, autism and intellectual disability [78]. Future researches may focus on VR applications on children with ADHD and CP. Akhutina et al administered VR therapy to the treatment group for 30-60 minutes, 6-8 times for 1 month in a semi-experimental study they conducted with 12 treatment and 9 control subjects. They showed that the visual-spatial abilities developed more

in the treatment group. They emphasized that VE-based spatial education was effective in children with complex disabilities [79]. Rosenbaum et al originally reported agency is essential component for our self-consciousness and the ability to control movements and interact appropriately with the environment, also the computer model help to investigate sense of agency in our experiment. Rosenbaum et al investigated that CP children's ability to correctly perceiving their own movement by training with cognitive process and motor control. The study consisted of 20 CP children in training group and 20 CP children in control group trained for at least 30 min daily in the 20 weeks period using the internet based home training system 'move it to improve it (Mi Tii)" and CP training group continued their routine daily life activities. Their results proved that children with CP improve their ability to determine whether they themselves or a computer are responsible for the movement of an observed object following 20 weeks of an inter active computer training designed to increased sensory-motor interaction [80].

Children with CP also generally occur pain and this affect to daily life activities, participation in rehabilitation, social life. Pain is also important for children to reduce motivation that induce human action. Distraction is one of the successful methods to reduce pain and behavioral distress for children suffered by pain. Pillay reported that interactive distraction that child attend activity the distraction task continuously require central attention resources much more effective than passive distraction activities that do not necessary management of central attentional functions such as watching cartoons. These interactive distraction activities consist of videogames, interactive musical storybooks, interactive toy robots and educational electronic games that reduce acute pain in children [81]. Law et al aimed to investigate effect of passive and active distraction task. They assessed pain by cold pressure tolerance. Participants separated two groups according to their age (6-9 years and 10-15 years). Because children react distraction differently associated to the age. Researches explained that attentional control improve rapidly during early childhood and develop greatly between 7-9 years and is relatively mature by 12 years. They used Nintendo Wii game system. Law et al found that there was significant improvement in pain tolerance all the interactive and passive distraction. But interactive distraction by increasing attentional load resulted higher improvements in pain tolerance. Their results are supported to the other researches in literature. In addition their findings showed that there were developmental differences on response to interactive distraction. Both of children have benefits on passive and interactive distraction but especially interactive distraction is much better. Also, older children response pain interactive distraction better than younger [82]. Current literature is required to research relationship between pain and VR interventions in CP.

13. Conclusion

We believe that VR provide new possibilities for the rehabilitation team of CP as the effect of active treatment and motivation together with functional use enable minimizing motor problems although the effect has not been completely shown in studies on VR applications in children with cerebral palsy due to heterogeneity of studies, sample size, outcome measures

and etc. In addition to many physical benefits the concept of "cerebral plasticity" are important for independent activity perception, especially for the treatment of motor problems from the perspective of physiotherapists, as well as therapy including play, fun and enjoy from the perspective of the child encourage us to complement the use of the VR systems in the rehabilitation of children.

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References

[1] Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, et al. A report: the definition and classification of cerebral palsy April 2006. Developmental medicine and child neurology Supplement. 2007 Feb;109:8-14. PubMed PMID: 17370477.

[2] Surveillance of Cerebral Palsy in E. Surveillance of cerebral palsy in Europe: a collaboration of cerebral palsy surveys and registers. Surveillance of Cerebral Palsy in Europe (SCPE). Developmental medicine and child neurology. 2000 Dec;42 (12):816-24. PubMed PMID: 11132255.

[3] Ashwal S, Russman BS, Blasco PA, Miller G, Sandler A, Shevell M, et al. Practice parameter: diagnostic assessment of the child with cerebral palsy: report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society. Neurology. 2004 Mar 23;62 (6):851-63. PubMed PMID: 15037681.

[4] Rosenbaum P, Stewart D. The World Health Organization International Classification of Functioning, Disability, and Health: a model to guide clinical thinking, practice and research in the field of cerebral palsy. Seminars in pediatric neurology. 2004 Mar;11 (1):5-10. PubMed PMID: 15132248.

[5] Meyer-Heim A, van Hedel HJ. Robot-assisted and computer-enhanced therapies for children with cerebral palsy: current state and clinical implementation. Seminars in pediatric neurology. 2013 Jun;20 (2):139-45. PubMed PMID: 23948688.

[6] (WHO) WHO. International Classification of Functioning, Disability and Health. Geneva. 2001; World Health Organization.

[7] Kantak SS, Stinear JW, Buch ER, Cohen LG. Rewiring the brain: potential role of the premotor cortex in motor control, learning, and recovery of function following brain

injury. Neurorehabilitation and neural repair. 2012 Mar-Apr;26 (3):282-92. PubMed PMID: 21926382.

[8] Lollar DJ, Simeonsson RJ. Diagnosis to function: classification for children and youths. Journal of developmental and behavioral pediatrics : JDBP. 2005 Aug;26 (4): 323-30. PubMed PMID: 16100508.

[9] Vargus-Adams J. Understanding function and other outcomes in cerebral palsy. Physical medicine and rehabilitation clinics of North America. 2009 Aug;20 (3): 567-75. PubMed PMID: 19643354. Pubmed Central PMCID: 2719719.

[10] Novak I, McIntyre S, Morgan C, Campbell L, Dark L, Morton N, et al. A systematic review of interventions for children with cerebral palsy: state of the evidence. Developmental medicine and child neurology. 2013 Oct;55 (10):885-910. PubMed PMID: 23962350.

[11] Beckung E, Hagberg G. Neuroimpairments, activity limitations, and participation restrictions in children with cerebral palsy. Developmental medicine and child neurology. 2002 May;44 (5):309-16. PubMed PMID: 12033716.

[12] Krageloh-Mann I, Cans C. Cerebral palsy update. Brain & development. 2009 Aug;31 (7):537-44. PubMed PMID: 19386453.

[13] Rosenbaum PL, Walter SD, Hanna SE, Palisano RJ, Russell DJ, Raina P, et al. Prognosis for gross motor function in cerebral palsy: creation of motor development curves. JAMA : the journal of the American Medical Association. 2002 Sep 18;288 (11): 1357-63. PubMed PMID: 12234229.

[14] Kerem Gunel M. [Rehabilitation of children with cerebral palsy from a physiotherapist's perspective]. Acta orthopaedica et traumatologica turcica. 2009 Mar-Apr;43 (2): 173-80. PubMed PMID: 19448358. Fizyoterapist bakis acisiyla beyin felcli cocuklarin rehabilitasyonu.

[15] Anttila H, Autti-Ramo I, Suoranta J, Makela M, Malmivaara A. Effectiveness of physical therapy interventions for children with cerebral palsy: a systematic review. BMC pediatrics. 2008;8:14. PubMed PMID: 18435840. Pubmed Central PMCID: 2390545.

[16] Weindling AM, Cunningham CC, Glenn SM, Edwards RT, Reeves DJ. Additional therapy for young children with spastic cerebral palsy: a randomised controlled trial. Health technology assessment. 2007 May;11 (16):iii-iv, ix-x, 1-71. PubMed PMID: 17462166.

[17] Butler C, Darrah J. Effects of neurodevelopmental treatment (NDT) for cerebral palsy: an AACPDM evidence report. Developmental medicine and child neurology. 2001 Nov;43 (11):778-90. PubMed PMID: 11730153.

[18] Gordon C, Roopchand-Martin S, Gregg A. Potential of the Nintendo Wii as a rehabilitation tool for children with cerebral palsy in a developing country: a pilot study. Physiotherapy. 2012 Sep;98 (3):238-42. PubMed PMID: 22898581.

[19] Lotze M, Braun C, Birbaumer N, Anders S, Cohen LG. Motor learning elicited by voluntary drive. Brain : a journal of neurology. 2003 Apr;126 (Pt 4):866-72. PubMed PMID: 12615644.

[20] Tatla SK, Sauve K, Virji-Babul N, Holsti L, Butler C, Van Der Loos HF. Evidence for outcomes of motivational rehabilitation interventions for children and adolescents with cerebral palsy: an American Academy for Cerebral Palsy and Developmental Medicine systematic review. Developmental medicine and child neurology. 2013 Jul; 55 (7):593-601. PubMed PMID: 23550896.

[21] Marshall SJ, Gorely T, Biddle SJ. A descriptive epidemiology of screen-based media use in youth: a review and critique. Journal of adolescence. 2006 Jun;29 (3):333-49. PubMed PMID: 16246411.

[22] Wilson PN, Foreman N, Stanton D. Virtual reality, disability and rehabilitation. Disability and rehabilitation. 1997 Jun;19 (6):213-20. PubMed PMID: 9195138.

[23] Weiss PL, Rand D, Katz N, Kizony R. Video capture virtual reality as a flexible and effective rehabilitation tool. Journal of neuroengineering and rehabilitation. 2004 Dec 20;1 (1):12. PubMed PMID: 15679949. Pubmed Central PMCID: 546410.

[24] Sharan D, Ajeesh PS, Rameshkumar R, Mathankumar M, Paulina RJ, Manjula M. Virtual reality based therapy for post operative rehabilitation of children with cerebral palsy. Work. 2012;41 Suppl 1:3612-5. PubMed PMID: 22317271.

[25] Sandlund M, McDonough S, Hager-Ross C. Interactive computer play in rehabilitation of children with sensorimotor disorders: a systematic review. Developmental medicine and child neurology. 2009 Mar;51 (3):173-9. PubMed PMID: 19191834.

[26] Fehlings D, Switzer L, Findlay B, Knights S. Interactive computer play as "motor therapy" for individuals with cerebral palsy. Seminars in pediatric neurology. 2013 Jun;20 (2):127-38. PubMed PMID: 23948687.

[27] Andolsek D. Virtual reality in education and training. International journal of instructional media. 1995;22 (2):145-51.

[28] Weiss PL, Katz N. The potential of virtual reality for rehabilitation. Journal of rehabilitation research and development. 2004 Sep;41 (5):vii-x. PubMed PMID: 15558392.

[29] Snider L, Majnemer A, Darsaklis V. Virtual reality as a therapeutic modality for children with cerebral palsy. Developmental neurorehabilitation. 2010;13 (2):120-8. PubMed PMID: 20222773.

[30] Holden MK. Virtual environments for motor rehabilitation: review. Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society. 2005 Jun;8 (3):187-211; discussion 2-9. PubMed PMID: 15971970.

[31] Reid DT. Benefits of a virtual play rehabilitation environment for children with cerebral palsy on perceptions of self-efficacy: a pilot study. Pediatric rehabilitation. 2002 Jul-Sep;5 (3):141-8. PubMed PMID: 12581476.

[32] Geerdink Y, Aarts P, Geurts AC. Motor learning curve and long-term effectiveness of modified constraint-induced movement therapy in children with unilateral cerebral palsy: a randomized controlled trial. Research in developmental disabilities. 2013 Mar;34 (3):923-31. PubMed PMID: 23291509.

[33] Papavasiliou AS. Management of motor problems in cerebral palsy: a critical update for the clinician. European journal of paediatric neurology : EJPN : official journal of the European Paediatric Neurology Society. 2009 Sep;13 (5):387-96. PubMed PMID: 18778959.

[34] Brutsch K, Schuler T, Koenig A, Zimmerli L, Koeneke SM, Lunenburger L, et al. Influence of virtual reality soccer game on walking performance in robotic assisted gait training for children. Journal of neuroengineering and rehabilitation. 2010;7:15. PubMed PMID: 20412572. Pubmed Central PMCID: 2877051.

[35] Rizzolatti G, Craighero L. The mirror-neuron system. Annual review of neuroscience. 2004;27:169-92. PubMed PMID: 15217330.

[36] Pfeifer JH, Iacoboni M, Mazziotta JC, Dapretto M. Mirroring others' emotions relates to empathy and interpersonal competence in children. NeuroImage. 2008 Feb 15;39 (4):2076-85. PubMed PMID: 18082427. Pubmed Central PMCID: 3840169.

[37] Dancause N, Barbay S, Frost SB, Plautz EJ, Chen D, Zoubina EV, et al. Extensive cortical rewiring after brain injury. The Journal of neuroscience : the official journal of the Society for Neuroscience. 2005 Nov 2;25 (44):10167-79. PubMed PMID: 16267224.

[38] Garrison KA, Winstein CJ, Aziz-Zadeh L. The mirror neuron system: a neural substrate for methods in stroke rehabilitation. Neurorehabilitation and neural repair. 2010 Jun;24 (5):404-12. PubMed PMID: 20207851.

[39] Cross ES, Kraemer DJ, Hamilton AF, Kelley WM, Grafton ST. Sensitivity of the action observation network to physical and observational learning. Cerebral cortex. 2009 Feb;19 (2):315-26. PubMed PMID: 18515297. Pubmed Central PMCID: 2638791.

[40] Sveistrup H. Motor rehabilitation using virtual reality. Journal of neuroengineering and rehabilitation. 2004 Dec 10;1 (1):10. PubMed PMID: 15679945. Pubmed Central PMCID: 546406.

[41] Winkels DG, Kottink AI, Temmink RA, Nijlant JM, Buurke JH. Wii-habilitation of upper extremity function in children with cerebral palsy. An explorative study. Developmental neurorehabilitation. 2013;16 (1):44-51. PubMed PMID: 23030054.

[42] Ketelaar M, Vermeer A, Hart H, van Petegem-van Beek E, Helders PJ. Effects of a functional therapy program on motor abilities of children with cerebral palsy. Physical therapy. 2001 Sep;81 (9):1534-45. PubMed PMID: 11688590.

[43] Thorpe DE, Valvano J. The effects of knowledge of performance and cognitive strategies on motor skill learning in children with cerebral palsy. Pediatric physical therapy : the official publication of the Section on Pediatrics of the American Physical Therapy Association. 2002 Spring;14 (1):2-15. PubMed PMID: 17053676.

[44] Chen KB, Savage AB, Chourasia AO, Wiegmann DA, Sesto ME. Touch screen performance by individuals with and without motor control disabilities. Applied ergonomics. 2013 Mar;44 (2):297-302. PubMed PMID: 23021630. Pubmed Central PMCID: 3572909.

[45] Lee D. The state of the touch-screen panel market in 2011. Inf Disp. 2011;27:12-6.

[46] Reid D. Virtual reality and the person-environment experience. Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society. 2002 Dec;5 (6):559-64. PubMed PMID: 12556119.

[47] Galvin J, Levac D. Facilitating clinical decision-making about the use of virtual reality within paediatric motor rehabilitation: describing and classifying virtual reality systems. Developmental neurorehabilitation. 2011;14 (2):112-22. PubMed PMID: 21410403.

[48] Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. Physical therapy. 2008 Oct;88 (10):1196-207. PubMed PMID: 18689607.

[49] Burdea GC, Jain A, Rabin B, Pellosie R, Golomb M. Long-term hand tele-rehabilitation on the PlayStation 3: benefits and challenges. Conference proceedings : Annual International Conference of the IEEE Engineering in Medicine and Biology Society IEEE Engineering in Medicine and Biology Society Conference. 2011;2011:1835-8. PubMed PMID: 22254686.

[50] Wille D, Eng K, Holper L, Chevrier E, Hauser Y, Kiper D, et al. Virtual reality-based paediatric interactive therapy system (PITS) for improvement of arm and hand function in children with motor impairment--a pilot study. Developmental neurorehabilitation. 2009 Feb;12 (1):44-52. PubMed PMID: 19283533.

[51] Parsons TD, Rizzo AA, Rogers S, York P. Virtual reality in paediatric rehabilitation: a review. Developmental neurorehabilitation. 2009 Aug;12 (4):224-38. PubMed PMID: 19842822.

[52] Galvin J, McDonald R, Catroppa C, Anderson V. Does intervention using virtual reality improve upper limb function in children with neurological impairment: a systematic review of the evidence. Brain injury : [BI]. 2011;25 (5):435-42. PubMed PMID: 21401370.

[53] Wang M, Reid D. Virtual reality in pediatric neurorehabilitation: attention deficit hyperactivity disorder, autism and cerebral palsy. Neuroepidemiology. 2011;36 (1):2-18. PubMed PMID: 21088430.

[54] Reid D. The use of virtual reality with children with cerebral palsy:A pilot randomized trial. Therapeutic Recreation Journal. 2006;40:255-68.

[55] You SH, Jang SH, Kim YH, Kwon YH, Barrow I, Hallett M. Cortical reorganization induced by virtual reality therapy in a child with hemiparetic cerebral palsy. Developmental medicine and child neurology. 2005 Sep;47 (9):628-35. PubMed PMID: 16138671.

[56] Chen YP, Kang LJ, Chuang TY, Doong JL, Lee SJ, Tsai MW, et al. Use of virtual reality to improve upper-extremity control in children with cerebral palsy: a single-subject design. Physical therapy. 2007 Nov;87 (11):1441-57. PubMed PMID: 17895352.

[57] Jannink MJ, van der Wilden GJ, Navis DW, Visser G, Gussinklo J, Ijzerman M. A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study. Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society. 2008 Feb;11 (1): 27-32. PubMed PMID: 18275309.

[58] Mutlu A, Krosschell K, Spira DG. Treadmill training with partial body-weight support in children with cerebral palsy: a systematic review. Developmental medicine and child neurology. 2009 Apr;51 (4):268-75. PubMed PMID: 19207302.

[59] Meyer-Heim A, Borggraefe I, Ammann-Reiffer C, Berweck S, Sennhauser FH, Colombo G, et al. Feasibility of robotic-assisted locomotor training in children with central gait impairment. Developmental medicine and child neurology. 2007 Dec;49 (12): 900-6. PubMed PMID: 18039236.

[60] Lamontagne A, Fung J, McFadyen BJ, Faubert J. Modulation of walking speed by changing optic flow in persons with stroke. Journal of neuroengineering and rehabilitation. 2007;4:22. PubMed PMID: 17594501. Pubmed Central PMCID: 1913055.

[61] Mockford M, Caulton JM. The pathophysiological basis of weakness in children with cerebral palsy. Pediatric physical therapy : the official publication of the Section on Pediatrics of the American Physical Therapy Association. 2010 Summer;22 (2):222-33. PubMed PMID: 20473109.

[62] Chen CL, Chen CY, Liaw MY, Chung CY, Wang CJ, Hong WH. Efficacy of home-based virtual cycling training on bone mineral density in ambulatory children with cerebral palsy. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2013 Apr;24 (4):1399-406. PubMed PMID: 23052930.

[63] Bryanton C, Bosse J, Brien M, McLean J, McCormick A, Sveistrup H. Feasibility, motivation, and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy. Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society. 2006 Apr;9 (2): 123-8. PubMed PMID: 16640463.

[64] Burdea GC, Cioi D, Kale A, Janes WE, Ross SA, Engsberg JR. Robotics and gaming to improve ankle strength, motor control, and function in children with cerebral palsy--a case study series. IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society. 2013 Mar;21 (2):165-73. PubMed PMID: 22773059.

[65] Peng YC, Lu TW, Wang TH, Chen YL, Liao HF, Lin KH, et al. Immediate effects of therapeutic music on loaded sit-to-stand movement in children with spastic diplegia. Gait & posture. 2011 Feb;33 (2):274-8. PubMed PMID: 21185725.

[66] El-Shamy SM, Abd El Kafy EM. Effect of balance training on postural balance control and risk of fall in children with diplegic cerebral palsy. Disability and rehabilitation. 2013 Sep 13. PubMed PMID: 24032716.

[67] Brien M, Sveistrup H. An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy. Pediatric physical therapy : the official publication of the Section on Pediatrics of the American Physical Therapy Association. 2011 Fall;23 (3):258-66. PubMed PMID: 21829120.

[68] Bruijn SM, Meijer OG, van Dieen JH, Kingma I, Lamoth CJ. Coordination of leg swing, thorax rotations, and pelvis rotations during gait: the organisation of total body angular momentum. Gait & posture. 2008 Apr;27 (3):455-62. PubMed PMID: 17669652.

[69] Allum JH, Bloem BR, Carpenter MG, Hulliger M, Hadders-Algra M. Proprioceptive control of posture: a review of new concepts. Gait & posture. 1998 Dec 1;8 (3):214-42. PubMed PMID: 10200410.

[70] Barton GJ, Hawken MB, Foster RJ, Holmes G, Butler PB. The effects of virtual reality game training on trunk to pelvis coupling in a child with cerebral palsy. Journal of neuroengineering and rehabilitation. 2013;10:15. PubMed PMID: 23391156. Pubmed Central PMCID: 3571979.

[71] Yamaki K, Rimmer JH, Lowry BD, Vogel LC. Prevalence of obesity-related chronic health conditions in overweight adolescents with disabilities. Research in developmental disabilities. 2011 Jan-Feb;32 (1):280-8. PubMed PMID: 21115323.

[72] Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: a systematic review. Archives of pediatrics & adolescent medicine. 2010 Jul; 164 (7):664-72. PubMed PMID: 20603468.

[73] Maher CA, Williams MT, Olds T, Lane AE. Physical and sedentary activity in adolescents with cerebral palsy. Developmental medicine and child neurology. 2007 Jun;49 (6):450-7. PubMed PMID: 17518932.

[74] Mitchell L, Ziviani J, Oftedal S, Boyd R. The effect of virtual reality interventions on physical activity in children and adolescents with early brain injuries including cere-

bral palsy. Developmental medicine and child neurology. 2012 Jul;54 (7):667-71. PubMed PMID: 22283557.

[75] Hurkmans HL, van den Berg-Emons RJ, Stam HJ. Energy expenditure in adults with cerebral palsy playing Wii Sports. Archives of physical medicine and rehabilitation. 2010 Oct;91 (10):1577-81. PubMed PMID: 20875517.

[76] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Jr., Tudor-Locke C, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Medicine and science in sports and exercise. 2011 Aug;43 (8):1575-81. PubMed PMID: 21681120.

[77] Spencer T, Biederman J, Wilens T. Attention-deficit/hyperactivity disorder and comorbidity. Pediatric clinics of North America. 1999 Oct;46 (5):915-27, vii. PubMed PMID: 10570696.

[78] Pollak Y, Weiss PL, Rizzo AA, Weizer M, Shriki L, Shalev RS, et al. The utility of a continuous performance test embedded in virtual reality in measuring ADHD-related deficits. Journal of developmental and behavioral pediatrics : JDBP. 2009 Feb;30 (1):2-6. PubMed PMID: 19194324.

[79] Akhutina T, Foreman N, Krichevets A, Matikka L, Narhi V, Pylaeva N, et al. Improving spatial functioning in children with cerebral palsy using computerized and traditional game tasks. Disability and rehabilitation. 2003 Dec 16;25 (24):1361-71. PubMed PMID: 14660204.

[80] Ritterband-Rosenbaum A, Christensen MS, Nielsen JB. Twenty weeks of computer-training improves sense of agency in children with spastic cerebral palsy. Research in developmental disabilities. 2012 Jul-Aug;33 (4):1227-34. PubMed PMID: 22502849.

[81] Pillay H. An investigation of cognitive processes engaged in by recreational computer game players: Implications for skills of the future.. Journal ofnResearch on Technology in Education. 2003; 34, :336–50.

[82] Law EF, Dahlquist LM, Sil S, Weiss KE, Herbert LJ, Wohlheiter K, et al. Videogame distraction using virtual reality technology for children experiencing cold pressor pain: the role of cognitive processing. Journal of pediatric psychology. 2011 Jan;36 (1):84-94. PubMed PMID: 20656761. Pubmed Central PMCID: 3107585.

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