Case Study: Using a Novel Virtual Reality Computer Game for Occupational Therapy Intervention

Abstract

The past decade has seen the emergence of rehabilitation treatments using virtual reality environments. One of the main advantages of using this technology is that it creates positive motivation. Currently, most virtual-reality-based games for children are not suitable for use in a therapeutic setting. This case study reports on the use of Growing with Timocco, a specially devised virtual reality computer game, as part of an occupational therapy regimen that addressed the developmental needs of a five-year-old patient diagnosed with dyspraxia, impaired postural structure, weak shoulder, and insufficient bilateral integration, bilateral coordination, and proprioception regulation. Developed specifically for use by occupational therapists and caregivers working with children, Growing with Timocco is equipped to provide exercises for both cognitive and motor skills, but most importantly, it provides a positive setting for this practice, by harnessing the advantages of VR to promote play, pleasure, and motivation.

1 Introduction

1.1 Virtual Environment Harnessed for Rehabilitation and Child Development

The rehabilitation process exploits brain plasticity, the ability to regain function by creating neural pathways generated in response to multiple repetitions and retraining (You et al., 2002; Hallet, 2005; Levin, 2006; Rand, Kizony, & Weiss, 2008). However, one of the major difficulties in the rehabilitation process concerns the problem of patient boredom, due to the intensive practice required. Another issue with which rehabilitation therapists must contend is the need to extend the intensive practice beyond the clinic and into the home. Underlying both of these difficulties is the issue of patient compliance (Barker & Brauer, 2005).

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For over a decade, virtual environments (VE) have been used for purposes of neurorehabilitation following various clinical pathologies, including stroke, spinal cord injury, traumatic brain injury, cerebral palsy, and intellectual disabilities (Golomb et al., 2010; Rose, Attree, & Johnson, 1996; Weiss, Sveistrup, Rand, & Kizony, 2009). By 2004, several studies had examined the use and noted the potential of a virtual reality environment for motor, cognitive and metacognitive related therapies (Weiss, Rand, Katz, & Kizony, 2004). The use of virtual environments in rehabilitation offers numerous advantages. The VE places the user/player in an environment that is similar to the real world in terms of the perceptual stimuli (Rizzo, 2002; Sheridan, 1992; Weiss & Jessell, 1998), which puts the user at ease. An essential feature in VE is the player's ability to manipulate some of the stimuli in the VE, and see—in real time—the outcome or the effect of the manipulative actions and adjust them accordingly. This interaction with the virtual environment creates engagement, a sense of presence within the VE, which is defined as "the perceptual illusion of nonmediation" (Lombard & Ditton, 1997). The sense of presence in the VE, where sensations are familiar and the player controls and manipulates part of the surrounding stimuli, renders the psychological effects of enjoyment and involvement (Lombard & Ditton).

In addition, the player's ability to monitor his or her own manipulative actions in real time makes VE a perfect tool for training purposes. This unique combination of purpose and pleasure creates intrinsic motivation in the user (Brooks & Petersson, 2005). Bracken and Lombard

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(2004) suggested that people, especially children, interact with computers socially. The researchers' study found that children who received positive encouragement from a computer were more confident in their ability, were more motivated, recalled more of a story, and recognized more features of a story than those children who received only neutral comments from the computer (Bracken & Lombard). In the context of rehabilitation therapy, motivation translates into patient compliance (Sveistrup et al., 2004; Weiss et al., 2009).

1.2 The Limitations of Existing VE-Based Programs

Merians, Poizner, Boian, Burdea, and Adamovich (2006) hypothesized that the use of VR for repetitive practice of hand motor skills exploits the nervous system's capacity for sensorimotor adaptation, making VR ideally suited for the rehabilitation of post-stroke patients. Their findings showed both group and individual improvements on most of the motion parameters (fractionation and range of movement) examined; however, they concluded that the existing delivery models could not provide the practice intensity needed to effect neural reorganization and functional changes, and noted that novel technologies, which could provide lower cost, home-based therapy should be explored (Merians et al.). Several researchers have pointed to the importance of a few key variables in VR programs for rehabilitation, which, if controlled by the clinican, would enhance the effects of the VR therapeutic modality, specifically: intensity of training; specificity of training; the program's sensitivity to changes in the quality of performance; the increments in task difficulty; and the quantity of feedback presented to the user in real time, as well as to the clinician for progress monitoring purposes (Merians et al.; Rand et al., 2008; Weiss et al., 2009).

The problem of motivating patients to exercise consistently so as to achieve the goals of rehabilitation is exacerbated when treating children. Studying the use of VR for rehabilitation of upper extremity reaching behaviors in four children with spastic cerebral palsy (CP), Chen et al. (2007) used two VR systems: a specially designed VR-based system for hand rehabilitation, and the commercially available EyeToy-Play VR system. Although a comparison was not included in the design of the study, the authors noted that the ability to adjust the degree of difficulty was an advantage of the lab-designed system, while the the attractive animation on the commercial system offered more fun. The Sony EyeToy system was also used successfully in a study with five children with hemiplegic CP: it elicited the desired movements, albeit with an emphasis on gross motor functions, and was found to be enjoyable and even acceptable as a home-based therapy. However, certain technical difficulties were experienced, and, in general, users with greater functionality in the hemiplegic arm performed more targeted movements than did their more severely disabled counterparts (Li, Chau, Lam-Damji, & Fehlings, 2009). Brooks and Petersson (2005) also used the eyetoy for therapeutic purposes with children, and specifically noted that well functioning (hospitalized) children found that the game provided mostly negative feedback. In addition, the speed was either too quick or too slow, both excesses resulting in boredom on the part of the child.

The conventional rehabilitation treatment methods in the framework of pediatric occupational therapy are based, for the most part, on the neurodevelopmental treatment (NDT) approach. This type of intervention, which is commonly used with children with neural impairments, especially CP, focuses on reducing motor obstructions, strengthening muscles, and stretching shortened muscles, to achieve healthier movement patterns (Langhammer & Stanghelle, 2003). This treatment requires practicing movement components, such as weight transferring and stretching, in a symmetrical arrangement, which does not induce motivation, and furthermore is completely disconnected from the patient's world of context. Consequently, patients often have difficulty both cooperating and continuing to practice consistently over time. These difficulties are intensified when dealing with young patients, since they are not aware of the significance of practicing or of its implications for their ability to function. Children have a hard time making a concerted effort for the purpose of therapy, all the more so if this practice is accompanied by pain or discomfort, without the benefit or dis-

traction of play and immediate experience. According to Anderson, Hinojosa, and Strauch (1987), the neurodevelopmental approach does not include any play activities.

A variety of VR technologies have been designed for rehabilitation purposes, with the aim of integrating experiences of fun and play in the rehabilitation process, and thus encouraging the patient to practice consistently in order to improve functionality. Thus, such technologies may be found in rehabilitation institutes and hospitals. The patient enjoys the use of these technologies during the process of in-hospital rehabilitation or during a stay at the rehabilitation institute. Once discharged, the patient returns home and is expected to continue the rehabilitation process at home and in the community; however, at this point the assistive technologies are no longer available to the patient. They are not an integral part of treatment in community clinics or at home, due to the prohibitive cost of acquiring the systems that support these technologies.

Due to the fact that VR technologies have clear benefits for rehabilitation, as described previously, and especially due to the ability of the VR technology to positively engage pediatric patients with the rehabilitation tool and thus increase their motivation (Green & Wilson, 2012), individual patients often make use of similar technologies from the world of entertainment. In other words, they adopt them as part of their rehabilitation practice after being discharged. In effect, these are affordable, off-the-shelf software programs (such as the Wii), which are intended for use by the general public for the purpose of entertainment.

While these entertainment programs afford the patient the experience of play, they frequently miss the rehabilitation target and, potentially, could harm the patient, if used without supervision. These commercial games are often associated with extreme intensity and therefore they encourage multiple and often wild movements, performed without the careful intent that is required in performing rehabilitative exercises. Therapy calls for monitored movements, gradual increase in the range of movement, motor control, and adaptive rehabilitation of movement patterns, none of which can be exercised in a gaming environment.

1.3 Growing with Timocco—A New VR-Assisted Tool for Pediatric Rehabilitation

The innovation that Growing with Timocco introduces into the world of VR-assisted rehabilitation is the integration of the availability and accessibility afforded by the commercial games, combined with the therapeutic-developmental principles that are typically found in the more complex and expensive VR programs. The system itself adds the significant advantage of operating on a home PC, enabling patients to continue their rehabilitative practice within the home. Thus, the patient can enjoy the convenience of easy accessibility, and practice at home by using a system that is based on therapeutic principles; that is, an activity that provides just the right challenge and that is meaningful to the child. Together, these two principles serve to empower the patient, encouraging the child to cope and to do the work necessary in order to overcome the disabilities.

The Growing with Timocco program is also appropriate for use in smaller clinics (such as community rehabilitation clinics and developmental centers).

As mentioned, one of the major disadvantages of the entertainment and gaming platforms is their nonmodular structure. This makes it difficult to adapt the game environment, for example, the level of difficulty and the pace of the activity, to the child's cognitive and motor abilities and to the goals of the therapy. The game environment of Growing with Timocco was specifically designed for use in a therapeutic context; as a result, anyone, whether the therapist, patient, parent, or educator, can make the necessary adjustments so that the activity corresponds to the patient's needs and stage of rehabilitative development. This ensures that progress will be carefully monitored and gradual.

However, with the Growing with Timocco system, it is possible to scale the level of difficulty of the activity and to choose a particular goal to focus on, such as increasing muscle tone, improving bilateral coordination, increasing range of motion and midline crossing, or goals related to attention and perception skills. In addition, the person overseeing the patient's therapeutic exercises can control numerous parameters within the game environment,

such as background, sounds, number of distractors, stimulus placement, and so on. These optional adjustments are essential in a system designed for therapeutic purposes, in order to create a positive and thus empowering experience. At the same time, these tailored adjustments serve to preclude the possibility of a frustrating experience, which might lead the patient to abandon the therapy. The overall goal is to help patients cope with difficulties or pain, by means of an interactive game that encourages continuous practice over time. The ability to choose a skill and the degree of challenge is also significant for encouraging the patients to adopt correct movement patterns, thus permitting continuous progress toward improved functionality or rehabilitation. Indeed, it is the ability to modify the activity to correspond with the patient's needs that determines the quality of treatment and it affects the patient's ability to persevere and comply with the demands of the therapeutic program.

An attribute that is unique to this VR PC-based rehabilitation platform is the ability to save data to a server, a feature which provides the advantage of tracking the patient's progress over time, as well as collecting data for research purposes.

Growing with Timocco was created and designed to provide occupational therapy practice in the community at large as well as in the privacy of one's home. At the other end of the VR spectrum are the advanced and sophisticated programs created by professionals for the single purpose of serving a therapeutic function. Growing with Timocco is a new addition in this area as well, since it too was created by professionals specifically to serve therapeutic purposes. Here its unique advantage goes beyond its affordable price tag: the Growing with Timocco system was designed to address the therapeutic needs of an age group that until now has been overlooked. This is the first system built for conducting rehabilitation and developmental remedial work with children, with the program's components tailored to address the array of children's developmental needs.

The contents and the graphics of the game environment appeal to the sensibilities of young children (ages 3 through 8). The user interface is simple and clear, so the graphics and the sounds of the game are not overwhelming. The icons are large and there is a strong contrast between the colors of the objects in the game, in order to make it easier for the child to distinguish between the different objects and buttons. The game environment is not flooded with visual and auditory stimuli: there is minimal movement in the background (which is also adjustable: plain background/background with movement/background without movement), and the sounds are repetitive and soft (also adjustable: mute and volume control/sounds emitted only when the child acts on an object in the game/full sound). The ability to adjust these stimuli allows the child to focus on the main task without distractions.

Also, the character of the monkey, Timocco, encourages children to challenge themselves and provides positive, gentle, and supportive feedback with frequent reinforcements (such as thumbs up signs or dancing animation of the monkey). The children, who feel pleased and encouraged by the monkey's cheering, are likely to play again. Furthermore, the game environment is free of noneducational content such as violence or competition.

Navigating the game environment is straightforward and intuitive. To enter the game, the child must point with both hands at the figure of Timocco the monkey, which represents the specific game the child wishes to play (Timocco pops soap bubbles in the tub, Timocco is carried in the air by balloons, and so on). All of these features distinguish Growing with Timocco from virtual platforms created for the use of adults in rehabilitation.

Another significant principle that guided the design of Growing with Timocco is ease of use, for both the patient and the therapist or caregiver. It is only by virtue of this aspect that the game platform can actually be used by its intended audience and thus may contribute to the field of VR-assisted rehabilitation. The platform features a user-friendly interface, which makes it more accessible to adults who might not be comfortable handling computers. Simplicity of use means that the child can participate in decisions to switch from one game to another and in selecting certain features of the game.

The Growing with Timocco game environment was designed based on neurodevelopmental approaches, which emphasize the use of numerous dimensions to encourage motor acquisition (Anderson et al., 1987). In a

similar fashion, with the program Growing with Timocco, patient treatment can encompass several movements and positions: arm movement practice can be on the sagittal plane (vertically, resisting gravity), the frontal (horizontal) plane, and the contralateral plane (hand reaching toward the other side of the body), which includes upper body rotation and crossing the midline. Neurodevelopmental approaches, such as the Lovaas Model of Applied Behavior Analysis, emphasize that the ability to differentiate the movements of various body parts signifies the maturity of the central nervous system, and claim that the ability to coordinate bilateral hand movements when manipulating an object or a game is an indication of a high aptitude of movement differentiation. The game environment of Growing with Timocco encourages smooth and coordinated bilateral hand movements, in which either one hand accompanies the other or the hands need to be brought together simultaneously (as in clapping). It also encourages static and dynamic positioning of the arms at or above shoulder level, as well as stretching to the side, moving away from the center of gravity, thus creating vestibular and postural challenges (Langhammer & Stanghelle, 2003). This repertoire of movements makes it suitable for treating numerous pediatric pathologies, such as CP, motor and coordination impairments, and various genetic disorders (e.g., Down syndrome, Fragile X syndrome, etc.). The wide repertoire of movements increases the options when modulating the program to match the patient's needs. One such modulation is the requirement to use both hands to complete a task. This corresponds to the therapeutic goal of bilateral coordination, or in the case of hemiparesis, encouraging the use of the weaker hand or arm.

Given that the level of functional ability varies widely from patient to patient, the program's modularity is one of its most important advantages. It is important to be able to select not only the proper type of game for therapy, and the proper plane of movement, but also the breadth of movement within which the patient functions during a particular game. Children with partial paralysis or impaired movement in upper or lower extremities have a limited range of movement; therefore, the arena in which they are asked to practice movement should be tailored to match that range. Growing with Timocco makes this type of adjustment possible, by scaling the playing field to match the child's range of movement. Thus, in the case of a child who is unable to extend his or her arms fully to the side, even a minimal movement, which may require a great deal of effort, will be shown as effective within the task range. This feature of the program enables the caregiver or therapist to make sure that the challenges are presented to the patient in a gradual sequence, matching the level of difficulty to the patient's rate of progress. Consequently, children with a very limited range of movement can experience success. By manipulating this feature in the opposite direction, that is, minimizing the effect of the patient's movements, the program can be used for treating children with balance-related difficulties. Thus, when tasks require a slightly wider range of movement, children must extend their limbs, shifting their center of gravity in the process, which challenges the vestibular system.

Typically, when treating perception or motor difficulties that are less severe than CP, both pediatric occupational therapy and physiotherapy rely on additional therapeutic approaches, which require that the child be actively involved and which draw on the child's areas of interest. Cognitive Orientation to Occupational Performance (CO-OP) is a cognitive approach for improving motor skills of children with Developmental Coordination Disorder (DCD). The child who is the focus of this program is encouraged to choose the therapeutic goals and activities. It is therefore intended for children with healthy metacognitive aptitudes who are mature enough to assess their performance of a given task (Missiuna, Mandich, Polatajko, & Malloy-Miller, 2001). Other client-centered approaches also emphasize the importance of involving the patient in selecting the therapeutic goals and activities (Sumision, 1999). When working with children, the ability to connect to the child's world in terms of interests and subject matter is crucial for increasing motivation during therapy. The VR environment in Growing with Timocco is in line with these therapeutic approaches: it is the first VR-based therapeutic program in which the contents are suited to the interests of young children, offering a variety of

activities from which they can select those that are most appealing to them.

One of the unique features of Growing with Timocco is the ability to incorporate an additional player in the therapeutic activity. With two players engaged (parent–child, therapist–child, or two children) in the game, the system can be tailored to match the needs, abilities, and preferences of each of the participants. This feature is of the essence for addressing the needs of children with communication disorders. While challenging the children in their area of difficulty, the game provides a reason for practicing their communication skills in a safe framework, which is both constant and predictable. In turn, this sense of safety encourages them to communicate with and take into consideration the presence of the other within the shared play space.

The game addresses not only motor but also cognitive needs, through tasks that require the child to exercise any or a combination of the following skills: categorizing; quantifying, and working with numbers; visual perception and discrimination (distinguishing colors, shapes, and distractors vs. relevant stimuli); and visual and auditory memory of sequences. Therefore, the program is intended for use with children with cognitive or general developmental delays. At the high end of the functional spectrum, the game is intended for use with children diagnosed with ADD/ADHD. Through the game, the child can learn to divide attention, delay reactions, and filter distractors, all within an environment that encourages monitoring of movement.

This case study describes short-term use of Growing with Timocco, as an integral part of occupational therapy sessions with a dyspraxic child who has demonstrated lack of motivation to cope with his difficulties.

1.4 Design and Features of Growing with Timocco

The technological solution for tracking movement was developed by adopting advanced technologies from the field of computational learning and implementing them toward image processing. The development of the product then involved movement tracking using a USB camera and passive sensors. The type of tracking used here is intended for motor therapy and is based on professional knowledge—specifically, clinical assumptions—about patients' motor and cognitive conditions and the type of practice to be undertaken using this game platform.

The sensors are spherical-shaped gloves worn by the patient and can be adjusted according to the particular child's needs and abilities. Most often, the camera is positioned at the top of the screen and the child is at a distance of about 1 m. The child's image appears in a small video window on the screen, to enable self-monitoring. With the help of the therapist or the supervising adult, the program is quickly calibrated by bringing the two gloves together at the center of the screen. From that point on, the system recognizes and responds to the movement of the sensors, and the child can begin playing. The sensors' movement is shown as two balls (the default view) on screen, and the child needs to use this information and that provided by his or her image in the video window to determine what kind of movement is required to fulfill the task of the game. The representation of the sensors on the screen changes according to the task and the game selected (pins, spray cans, the arms of Timocco the monkey, etc.)

Growing with Timocco includes a series of five fun and educational games, intended to provide practice and improve motor and cognitive abilities of children ages 3 to 8 with special needs and developmental delays. All of the games feature the same character, Timocco, the friendly monkey. While navigating through the different games, the child plays within Timocco's world, by either moving the monkey's arms, or interacting with the monkey. The environment changes from game to game, alternating between home, the yard, the beach, and even in the sky. In each activity, the child uses the motion-tracking gloves to control on-screen movements and manipulate objects in the VE, thus performing the particular task of each game.

Each of the five games (balloons, falling fruit, bubble bath, photo album, and kitchen drummer) features nine incremental levels of difficulty, and each level consists of three sessions (of 2–4 min) of graded difficulty. The degree of difficulty is determined through the combination of several parameters: the pace of the game, the

number of distractors presented at a given time, the rate at which distractors are introduced on screen, and the size of the object that is the target of the child's actions. The child receives visual feedback on his or her progress, displayed by the monkey's ascent on a ladder located on the left side of the screen and, in addition, each successfully accomplished task is acknowledged with auditory feedback.

The games are not competitive: mistakes are not counted and the time to complete a given task is not limited. The level of difficulty and the incremental progress from level to level are controlled and determined by the therapist. Each game can be adjusted to exercise one or more motor/cognitive skills; for example, bilateral coordination, crossing the midline, hand–eye coordination, posture, visual discrimination, short-term memory, or attention.

The therapist is able to analyze logged information, including the number of errors made, the number of hits, response time, time on task, performance efficacy, the path of hand motion, as well as other data that serve to evaluate the client's progress. This information helps the therapist identify in which specific areas the child is making progress and judge the degree to which the game is effective in helping the child and therapist attain their goals.

2 Case Description

A public HMO in Israel referred a male patient, 5 years and 2 months of age, to occupational therapy, following the kindergarten teacher's request for an evaluation.

He arrived at the occupational therapy clinic in January, 2010, for the first (HMO-approved) installment of 12 weekly therapy sessions. A diagnosis was conducted by the occupational therapist, using the Movement Assessment Battery for Children (M-ABC; Henderson & Sugden, 1992), the Miller Assessment for Preschoolers (MAP; Miller, 1988, 1982), and the Beery-Buktenica Visual-Motor Integration Test (Beery, 1997). In addition, a parent questionnaire and a kindergarten teacher questionnaire (both internally designed by the HMO) were completed by the relevant parties.

Findings included poor motor control and coordination (dyspraxia), impaired postural structure, a weak shoulder girdle, and immature flexor and extensor muscles of the trunk. During the clinical examination, the child demonstrated insufficient bilateral integration as he switched hands when coloring different sides of the page. He had difficulty throwing and catching a ball, coordinating bilateral motions in order to run, and difficulty regulating proprioception (deep muscle sensation). The combination of these issues made it difficult for him to remain seated upright at a table for an extended period of time. These findings were in line with the kindergarten teacher's report, which described the child as tiring quickly when seated at a table, refraining from activities such as drawing and art, and generally demonstrating difficulty with motor activity and movement through space. Indeed, due to his difficulty maintaining body posture, he tended to fall and he tired easily; consequently, the quality of his movements decreased significantly after short periods of time. This led to frustration and avoidance behaviors.

The following occupational therapy goals were determined:

1. To improve the child's performance in time-consuming physical activities.
2. To instill in the child a sense of self-efficacy while he moves in space, by providing positive reinforcement to his improved performance. A sense of success would motivate the child to challenge himself. Instead of avoiding activities, increased confidence would enable him to approach and experience a variety of motor activities.
3. To improve praxis, emphasizing bilateral coordination and crossing the midline, so as to facilitate participation in social activities.

2.1 Procedure

2.1.1 Measures. The system records samples of the patient's movements and provides performance-related data. In the current case study, three outcome measures were recorded by the system: (1) number of errors; (2) number of missed objects; and (3) performance efficiency (percentage of hits and misses).

Figure 1. *Screen capture of the Falling Fruit game.*

Other performance criteria were assessed by means of observation: the child's motivation, the child's behavior, the number of pauses needed, and the child's persistence in facing the challenge.

2.1.2 Intervention. The virtual reality computer game Growing with Timocco was introduced for the first time in the third occupational therapy session. By this stage of the therapy, it was clear how the game could best be utilized for the patient's needs. The Growing with Timocco gaming environment was incorporated in the child's occupational therapy sessions for three consecutive weeks. Each time, the play session was introduced during the same part of the session and was limited to 15 consecutive minutes (of a 45-min session).

For the purpose of this study, the child was directed to play the same game Falling Fruit at each session, in order to render a valid comparison. In this game, as the child controlled Timocco's hands by moving his own hands, his goal was to try to catch the fruit items as soon as they appeared at the top of the screen and place them in the appropriate basket (categorized by fruit type) at the bottom of the screen (see Figure 1). In performing these tasks, the patient practiced precision in motor tasks, crossing the midline, hand–eye coordination, visual discrimination, reaction speed, and categorization.

2.2 Session 1

The child approached the game happily. He got settled in front of the screen and placed the gloves on his hands with the therapist's help. On his first attempt at the game, he found it difficult to control and adjust the accuracy of his movements in order to place the fruit in the correct basket. Consequently, he accumulated a large number of errors (see Figure 2[a]). In addition, the child's reaction was very slow, causing him to miss many of the falling fruits (see Figure 2[b]). In general, the

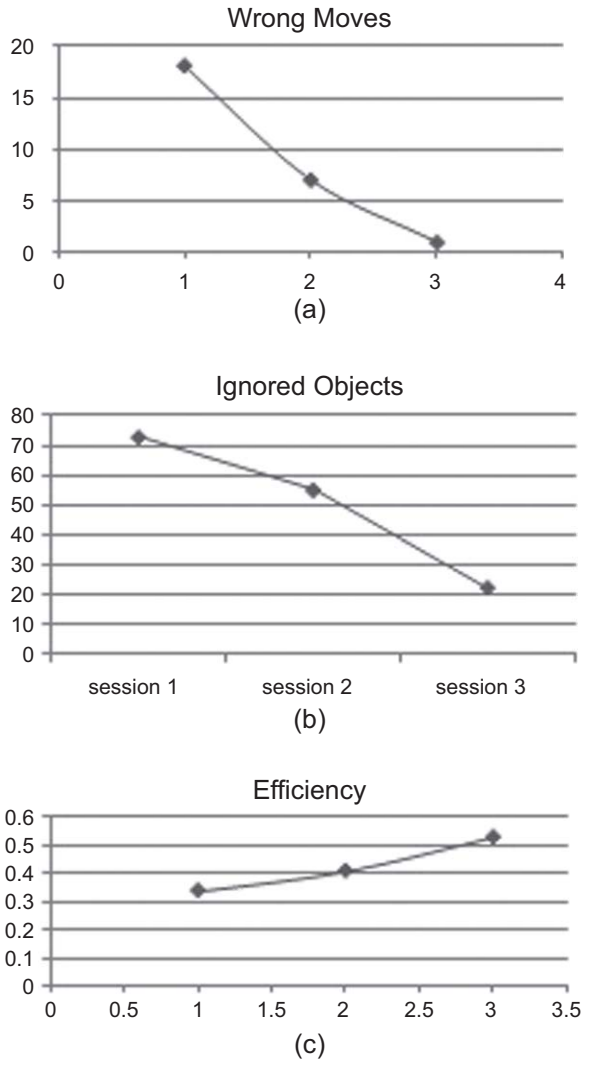

Figure 2. *(a) The child's progress in terms of the average number of inaccurate moves (resulting in mistakes) throughout the sessions. (b) The child's progress in terms of the average number of fruits ignored (missed) throughout the sessions. (c) The child's performance efficiency calculated by the numbers of successes, mistakes, and number of fruits that were missed. Efficiency = Correct moves/(Correct + Ignored + Wrong).*

quality of his play and the efficiency of his performance were very low (see Figure 2[c]). Throughout the game, it was obvious to the therapist that the difficulty did not stem from cognitive impairment (he quickly understood the instructions to the task); the problem was clearly related to his motor skills.

However, unlike his usual behavioral pattern, the child was motivated to succeed and did not give up trying despite the need to be persistent and make a continuous effort. At the end of the game session, he got up, shook his hands so as to relax the muscles and lay down on his back. He needed to rest and it was obvious that the activity had demanded a great deal of effort.

2.3 Sessions 2 and 3

The child came to both sessions ready and motivated. He already knew the game and what to expect.

At the second session, he asked to explore more games; however, in order to keep the tasks consistent for this case study protocol, the therapist suggested that he try other games as soon as he finished playing the falling fruit one. He complied happily and started to play. At the end of the game, he immediately asked to try out another game and did not need to rest after playing, as he did the first time. He subsequently played two more games and, unlike his performance in the first session, this time he only needed short breaks in between games and showed no sign of fatigue at the end of the playing session.

3 Results

A significant improvement in performance was noted between the first and second sessions, and this trend was also apparent between the second and third session (see Figure 2).

Given that the number of sessions was small, we cannot conclude that there was a significant improvement in the child's motor skills. However, we can assume that the very exposure to the Growing with Timocco game platform, which provided an appropriate level of challenge, an activity that interested him and the experience of success, served to increase the child's motivation to attempt a variety of new activities, at home and in kindergarten, which until that point he had made an effort to avoid. This may explain the quick improvement seen in the child's functioning; although a significant musculoskeletal improvement in such a short time is unlikely, there can be no doubt that the child's ability to focus his efforts and cope with difficulty did improve in this short time span.

The outcome measures indicated that the number of errors declined significantly between the first and the third session (see Figure 2[a]), there were fewer misses (see Figure 2[b]), and performance efficacy improved from one session to the next (see Figure 2[c]).

These results indicate enhancement of the skill used in the game; however, a broader assessment of progress, beyond the game environment, was necessary. To this end, the therapist conducted observations both during and after the playing period, when the patient was engaged in other types of activity. These observations were complemented by interviews with the parent and with the kindergarten teacher, in order to gain a broader picture of the child's functioning.

Despite the short-term intervention, the clinical observations demonstrated promising improvement in most of the goals set for the therapy, mostly in areas of self-esteem and motivation to cope with challenges, which in turn affected the child's overall performance.

1. The child's persistence in facing the challenge of spatial movement improved from one session to the next, and fewer and shorter pauses were required each time. These results indicate an improved ability to maintain static positions over time, as well as the lessening of motor fatigue.
2. Increased confidence and increased motivation were achieved. Seeing his improvement through the monkey's ascent up the ladder (on the left of the screen), and in the progression from level to level, instilled in the child a sense of success and increased his confidence. He kept saying "it's easy peasy" and urged the therapist to increase the level of difficulty. As he moved from one level to the next, he would look to his mother for approval, which she gave wholeheartedly. After playing the

virtual environment computer game, the child's newly acquired motivation served as a point of departure for the remainder of the therapy session. He was happy to sit at the table and draw Timocco the monkey. Despite his low self-esteem in activities related to graphomotor skills, and his tendency to avoid drawing assignments, he approached this task willingly. With the aid and guidance of the occupational therapist, the child was able to complete the drawing, after which he began coloring it. Without any prompting, he asked to continue the activity despite the challenge.

3. Improvements were observed in the patient's ability to maintain posture and in related motor skills. Other therapeutic activities that were conducted outside of the game environment indicated progress in throwing and catching a ball, and the child's posture when seated at a desk also improved: he sat up straight for longer periods and was less fidgety.

As this case study utilized a model of short-term therapy to demonstrate the effects of using the Growing with Timocco program, there was no opportunity to conduct the same set of diagnostic evaluations used at the beginning of the therapy for the sake of comparison. Consequently, the comparison that was conducted was based on the therapist's observations and the reports of the parents.

Indeed, these outcomes were further confirmed in the follow-up conversation with the child's parents, which revealed that there was noticeable change in the patient's play behaviors both at home and in kindergarten. He would approach and participate in games that he avoided prior to the intervention. The parents noted this behavior particularly in social games, such as Chutes and Ladders and catch. They also reported increased confidence and the child's enhanced ability in managing frustration and persisting, even in challenging situations.

The kindergarten teacher's report confirmed these findings. She noticed that the patient was able to continue in a single activity over longer periods of time, and that he appeared less tired and more confident in his abilities. The teacher added that the child experienced fewer instances in which frustration was expressed verbally (in exclamations such as "I can't") or physically (throwing himself on the ground during a soccer game), and that he was no longer in the habit of quitting a social game before it was over.

4 Discussion

This case study reviewed the use of a novel VR-based computer game, in which the advantages of VR were harnessed for therapeutic purposes. Data collected showed improved performance on the tasks of the game.

Although this was a short-term intervention, it appears that following it, the child managed to cope with motor activities better than before, and that there was an improvement in his overall functioning. Clearly, this improvement cannot be explained in terms of a significant change in motor skills; however, it can be attributed to an increased sense of self-efficacy and an increase in internal motivation, which led to better coping and an improvement in the child's functioning overall.

The virtual environment provides a safe place for trial and error and allows the child to experience pleasure, derived from exercising his or her own capabilities and internal motivation (Brooks & Petersson, 2005; Verhagen, Feldberg, Van Den Hooff, & Meents, 2009). Internal motivation, in turn, derives from a sense of self-efficacy, which is defined as the belief in one's own abilities to muster the cognitive resources and behavioral patterns necessary to cope with a given situation (Wood & Bandura, 1989, p. 408). Children are in the process of constructing their beliefs about themselves and their abilities, and they choose their goals based on these beliefs (Bandura, 1993).

A study by Shin (2009) found that self-efficacy contributes to play in the VR environment and affects players' sense of pleasure as well as their ability to cope. A sense of self-efficacy can emerge only in a game environment that provides challenges at an appropriate level that is not too far from the player's actual abilities. A challenge that is too difficult could lead to frustration or boredom, resulting in the player's refusal to continue playing. Thus, the game environment has a crucial effect on the child's willingness to play; and therefore, an

unmatched, inappropriate environment reduces the child's sense of control, which leads to diminished motivation (Bundy, 1997). In the game Growing with Timocco, the VR environment was designed so that it could be tailored to the child's abilities and needs; thus, it may be assumed that this feature led to an increased sense of self-efficacy and, in turn, greater motivation for coping with difficulties and challenges, which previously the child had preferred to avoid.

The advantages offered by virtual reality technology are heightened in Growing with Timocco, a program especially designed for therapeutic or rehabilitative purposes and intended for children. In addition, Growing with Timocco differs from commercially available programs in several aspects, which include isolating a skill-specific task tailored to the client's needs; and varying the task and grading its complexity, so as to monitor performance and allow for gradual progress, without risking client frustration. These unique features might make Growing with Timocco a valuable tool for both the clinician and the client.

Furthermore, while commercially available programs display the player within the virtual environment (Weiss et al., 2009, p. 308), in the current program, the player is not visibly present in the VE (although a video window is optional). Instead, the young player exercises his or her imagination and is thus transported into the VE, where he or she interacts with the character, Timocco the monkey, whose presence in the VE is reliable and constant. Thus, the "perceptual illusion" (Lombard & Ditton, 1997)—the hallmark of VR—is created by placing reality-based objects, interactions, and even the emotive elements of a relationship with the monkey in a virtual, explicitly imaginary environment. This perceptual illusion invites the child to enter the mindset referred to in the psychology literature as play.

Children's play serves numerous functions (Schell & Hall, 1983, p. 257). The first stage of child's play is the repetition of physical movements; the second stage is symbolic play, which incorporates the imagination. Vygotsky notes that even in its earlier developmental form, play starts with "an imaginary situation that initially is so very close to the real one" (Vygotsky, 1978, p. 103). He emphasizes that play develops as the child develops; however, it never loses its imaginary quality. "The development from games with an overt imaginary situation and covert rules to games with overt rules and a covert imaginary situation outlines the evolution of children's play" (Vygotsky, p. 96). Thus, the repetition of movements (evoking the earliest form and benefit of play) and the use of the imagination (the second and constant element of play) are recruited for the purposes of occupational therapy. The effects of play that are most pertinent to the goals of occupational therapy are intrinsic motivation, attention to means rather than ends, and *active* (emphasis in original) participation of the player (Rubin, Fein, & Vandenburg, 1983, in Bundy, 1991, p. 49). When involved in play, children (particularly young children) do not fully realize that they are doing beneficial exercises: positive reinforcements in combination with fun and enjoyment contribute to engagement and immersion in play.

Thus, the incorporation of a VE into a therapeutic game provides the optimal setting, as it affords the perceptual illusion (imaginary but similar to reality), the player's active participation, and the element of repeated movements, but with boredom and frustration eliminated through the therapist's manipulation of the game's features. Indeed, the VE created in this specially designed program is congruent with therapists' definition of an "environment of play," which includes the following components:

> (1) An array of familiar peers, toys or other materials likely to engage children's interest; (2) A [tacit] agreement between adults and children. . . that the children are free to choose from the array whatever they wish to do within whatever limits required by the setting. . .; (3) Adult behavior that is minimally intrusive or directive; (4) A friendly atmosphere designed to make children feel comfortable and safe; and (5) Scheduling that reduces the likelihood of children being tired, hungry, ill, or experiencing other types of bodily stress. (Rubin et al., 1983 in Bundy, 1991, p. 57)

As demonstrated, because the design of Growing with Timocco includes both a VE that facilitates immersion in play, as well as the ability to adapt the game to the child's specific needs, it may provide a useful tool that therapists

and parents can use to encourage the child to practice a variety of skills and increase the child's motivation to cope with motor and cognitive challenges.

References

Anderson, J., Hinojosa, J., & Strauch, C. (1987). Integrating play in neurodevelopmental treatment. *American Journal of Occupational Therapy, 41*(7), 421–426.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117–148.

Barker, R. N., & Brauer, S. G. (2005). Upper limb recovery after stroke: The stroke survivors' perspective. *Disability Rehabilitation, 27*(20), 1213–1223.

Beery, K. E. (1997). *The Beery-Buktenica VMI: Developmental test of visual-motor integration with supplemental developmental tests of visual perception and motor coordination: Administration, scoring, and teaching manual*. Parsippany, NJ: Modern Curriculum Press.

Bracken, C., & Lombard, M. (2004). Social presence and children: Praise, intrinsic motivation, and learning with computers. *Journal of Communication, 54*(1), 22–37.

Brooks, A. L., & Petersson, E. (2005). Play therapy utilizing the Sony EyeToy®. In M. Slater (Ed.), *Proceedings of the Eighth International Workshop on Presence,* 303–314.

Bundy, A. (1991). Play theory and sensory integration. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration: Theory and practice* (p. 57). Philadelphia: F.A. Davis.

Bundy, A. C. (1997). Play and playfulness: What to look for. In D. Parham & L. S. Fazio (Eds.), *Play in occupational therapy for children* (pp. 52–66). St. Louis, MO: Mosby-Year Book Inc.

Chen, Y.-P., Kang, L.-J., Chuang, T.-Y., Doong, J.-L., Lee, S.-J., Tsai, M.-W., et al. (2007). Use of virtual reality to improve upper-extremity control in children with cerebral palsy: A single-subject design. *Physical Therapy, 87*(11), 1441–1457.

Golomb, M. R., McDonald, B. C., Warden, S. J., Yonkman, J., Saykin, A. J., Shirley, B., et al. (2010). In-home virtual reality videogame telerehabilitation in adolescents with hemiplegic cerebral palsy. *Archives of Physical Medicine and Rehabilitation, 91*(1), 1–8.

Green, D. D., & Wilson, P. H. (2012). Use of virtual reality in rehabilitation of movement in children with hemiplegia—A multiple case study evaluation. *Disability & Rehabilitation, 34*(7), 593–604.

Hallet, M. (2005). Neuroplasticity and rehabilitation. *Journal of Rehabilitation Research and Development, 42*(4), 17–22.

Henderson, S. E., & Sugden, D. A. (1992). *The Movement Assessment Battery for Children*. London: Psychological Corporation.

Langhammer, B., & Stanghelle, J. K. (2003). Bobath or motor relearning programme: A follow up one and four years post stroke. *Clinical Rehabilitation, 17*(7), 731–734.

Levin, H. (2006). Neuroplasticity and brain imaging research: Implications for rehabilitation. *Archives of Physical Medicine and Rehabilitation, 87*(12, supplement), 1.

Li, W., Chau, T., Lam-Damji, S., & Fehlings, D. (2009). The development of a home-based virtual reality therapy system to promote upper extremity movement for children with hemiplegic cerebral palsy. *Technology and Disability, 8*(3), 107–113.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication, 3*(2). Retrieved from http://jcmc.indiana.edu/vol3/issue2/lombard.html

Merians, A. S., Poizner, H., Boian, R., Burdea, G., & Adamovich, S. (2006). Sensorimotor training in a virtual reality: Does it improve functional recovery poststroke? *Neurorehabilitation and Neural Repair, 20*(2), 252–267.

Miller, L. (1988, 1982). *Miller Assessment for Preschoolers*. San Antonio, TX: Psychological Corporation.

Missiuna, C., Mandich, A. D., Polatajko, H. J., & Malloy-Miller, T. (2001). Cognitive orientation to daily occupational performance (CO-OP), Part 1: Theoretical foundation. In C. Missiuna (Ed), *Children with developmental coordination disorder: Strategies for success* (pp. 69–81). New York: Haworth Press.

Rand, D., Kizony, R., & Weiss, P. L. (2008). The Sony PlayStation II EyeToy: Low-cost virtual reality for use in rehabilitation. *Journal of Neurologic Physical Therapy, 32*(4), 155–163.

Rizzo, A. (2002). Virtual reality and disability: Emergence and challenge. *Disability and Rehabilitation, 24*(11–12), 567–569.

Rose, F. D., Attree, E. A., & Johnson, D. A. (1996). Virtual reality: An assistive technology in neurological rehabilitation. *Current Opinion in Neurology, 9*(6), 461–467.

Rubin, K., Fein, G. G., & Vandenburg, B. (1983). Play. In P. H. Mussen (Ed.), *Handbook of child psychology* (4th ed.), Vol. 4: *Socialization, personality and social development* (pp. 693–774). New York: Wiley.

Schell, R. E., & Hall, E. (1983). *Developmental psychology today* (4th ed.). New York: Random House.

Sheridan, T. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Reality, 1*(1), 120–125.

Shin, D. H. (2009). The evaluation of user experience of the virtual world in relation to extrinsic and intrinsic motivation. *International Journal of Human–Computer Interaction, 25*(6), 530–553.

Sumision, S. (1999). Overview of client-centered practice. In S. Sumision (Ed.), *Client-centered practice in occupational therapy—A guide to implementation* (pp. 1–12). Edinburgh, UK: Churchill Livingstone.

Sveistrup, H., McComas, J., Thornton, M., Marshall, S., Finestone, H., McCormick, A., et al. (2004). Experimental studies of virtual reality-delivered compared to conventional exercise programs for rehabilitation. *CyberPsychology & Behavior, 6*(3), 245–249.

Verhagen, T., Feldberg, F., Van Den Hooff, B., & Meents, S. (2009). Understanding virtual world usage: A multipurpose model and empirical testing. *Proceedings of the 17th European Conference on Information Systems.* Retrieved from http://aisel.aisnet.org/ecis2009/98

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, Trans.). Cambridge, MA: Harvard University Press.

Weiss, P. L., & Jessel, A. S. (1998). Virtual reality applications to work. *Work, 11*(3), 277–293.

Weiss, P. L., Rand, D., Katz, N., & Kizony, R. (2004). Video capture virtual reality as a flexible and effective rehabilitation tool. *Journal of NeuroEngineering and Rehabilitation, 1*(12) doi:10.1186/1743-0003-1-12

Weiss, P. L., Sveistrup, H., Rand, D., & Kizony, R. (2009). Video capture virtual reality: A decade of rehabilitation assessment and intervention. *Physical Therapy Reviews, 14*(5), 307–321.

Wood, R., & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology, 56*(3), 407–415.

You, S. H., Jang, S. H., Kim, Y. H., Hallett, M., Ahn, S. H., Kwon, Y. H., et al. (2002). Virtual reality-induced cortical organization and associated locomotor recovery in chronic stroke. *Stroke, 36*(6), 1166–1171.