VIRTUAL REALITY IN REHABILITATION AND THERAPY

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SUMMARY – This paper describes virtual reality and some of its potential applications in rehabilitation and therapy. Some aspects of this technology are discussed with respect to different problem areas (sensorimotor impairments, autism, learning difficulties), as well as previous research which investigated changes within some motor and motivation parameters in relation to rehabilitation of children with motor impairments. Emphasis is on the positive effects of virtual reality as a method in which rehabilitation and therapy can be offered and evaluated within a functional, purposeful and motivating context.

Key words: *Virtual reality exposure therapy; Rehabilitation; Developmental disabilities; Hand; Motor skills*

Introduction

The notion of virtual reality (VR) was first introduced by Jaron Lanier in the late 1980s[1]. As an information technology expert, he has built a computer model using a graphic interface project, a virtual environment in which the user, with the help of special devices, begins to interact with graphic elements of that environment. It is precisely this possibility of interaction, which sets this medium apart from, for instance, video and television, as well as being the most important element that makes VR suitable for various fields like informatics, education, rehabilitation, medicine, entertainment, military technologies, space technologies, etc.

The development of VR has been closely tied to technological advances, primarily development of powerful computers, which can support the needs of graphic, three-dimensional (3-D) interfaces, i.e. the speed and the ability to give a detailed image of the virtual environment. By means of devices that facilitate visual, auditory, haptic or olfactory interaction between the person and the VR, a person can experience the presented VR as if it were part of the real world, either as a model/object that exists in the real world or as an abstract model/object (up to the level of science fiction) that is imaginary, but still understood by the person[2]. Furthermore, on the basis of the user's action (sound input, movement, etc.) through the above mentioned intermediating devices, the computer makes changes in the virtual graphic environment, thereby creating an illusion of the user's interaction and intervention within the VR.

According to Riva, the VR system consists of (a) external tools (visual, auditory, and haptic), which connect the user to the virtual environment; (b) internal tools (trackers, gloves, joysticks and exoskeletons, mouse), which trace the user's position and motion; (c) a system of graphic image rendering, which creates the virtual environment; and (d) the software and database, which are used to shape models/objects in the virtual world (shapes, textures, object motion)[1].

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Received May 1, 2013, accepted October 11, 2013

Virtual Reality in Education, Rehabilitation and Therapy

Some benefits of VR applied in rehabilitation, as mentioned by Schultheis and Rizzo, are the following: complete control over the stimulus and its consistency, the ability to vary the stimuli from simple to more complex ones, the ability to readily grade and record the patient's progress, ensuring a safe learning environment, the capacity to offer individualized treatment (according to the diagnosis and patient's needs), influence on the patient's motivation through the possibility to include playing in the rehabilitation process, etc.[3]. Within the field of motor rehabilitation, VR offers a relatively affordable rehabilitation environment, which allows for the effective inclusion of exercise repetition, evaluation of the effects, and motivation for adhering to a high number of repeated exercises, which are the key components of this kind of rehabilitation[4]. In this respect, VR is used in the rehabilitation of post-stroke and brain injury patients, in the orthopedic rehabilitation of patients with Parkinson's disease, in balance exercises, and in practicing everyday activities.

McComas *et al.* analyzed the possible application of VR in the education and rehabilitation of children, through assessing the work of other authors. They point out that VR can be used in learning and practicing new skills, in the evaluation and practicing of motor and/or cognitive functioning, in enhancing social participation and in improving the quality of life. The authors mention a number of examples where VR is used as an assistive technology in such activities. As in the case of children with blindness, virtual environment can present a source of auditory and/or tactile stimuli through which the child learns and acquires new skills. In children with impairments in the autistic spectrum, limiting the number of stimuli and encouraging children to concentrate on a particular task, and gradually increasing the number of stimuli can also be developed in a certain kind of VR. By implementing a structure that allows complex tasks to be broken down into more simple elements, VR can be a helpful and motivating tool for children with learning difficulties[5]. In addition, as reported by McComas *et al.*, Nemire and Crane allowed students with cerebral palsy to access a virtual science laboratory and to virtually manipulate objects in it using a heptic interface[5]. Researchers at the University of Nottingham have designed virtual environments that have provided students with developmental disabilities an opportunity to enhance their skills in everyday life activities such as visiting a post office or a supermarket, moving within a virtual house, driving in a virtual city that includes traffic and pedestrian crossings, skiing on virtual hills, etc. They also discuss the possibility of using VR in training mobility in children with physical disability, by enhancing perceptual-motor skills and cognitive-spatial abilities, as well as encouraging the child's sense of independence, confidence and personal control. As a concrete example of VR application in this area, the authors mention self-locomotion training using a motorized wheelchair in different circumstances (obstacles such as stairs, curbs, doors that are difficult to open, objects that are difficult to reach, and inappropriate expectations and comments from the environment). In hospitalized children, communication possibilities with the help of VR (video conferencing with family and friends, exchange of multimedia materials, etc.) presents a facility, which helps children cope with the illness and ease their stay in the hospital[5]. In a number of studies, VR has been used and its effects are being examined through rehabilitation programs based on the use of widely available gaming consoles such as Nintendo and Wii[6-9]. Furthermore, the authors of the described study express the need for further development and research on VR with regard to the target groups and problem areas, which requires evaluation of educational and/or rehabilitation programs based on VR and transfer of the results into the patient's real life.

Virtual Reality in Motor Rehabilitation of Children – Some Scientific Studies

Although it is a valid statement that for children, parents and experts from various disciplines, VR presents a modern way of learning based on computer technology, as noted by Sandlund *et al.*, the number of studies in this field is still very small. The same authors, within the scope of their investigation of interactive exercises for children with sensorimotor impairments, consider further challenges of including VR in the design of new interactive systems in this area of rehabilitation. Furthermore, the authors also consider the areas concerning evaluation of sensorimotor rehabilitation programs, such as activation intensity of muscle groups, types, range and speed of movement, eye-hand coordination, fatigue factor, and others[10].

Bart *et al*. assessed the effects of VR application in children with acquired brain damage (traumatic injuries, tumors, infections) and compared them with a healthy control group. Seventeen children (6-11 year old) participated in the experiment within 10 to 120 days of having sustained brain injury (experimental group) and 16 age-matched healthy children (control group). The participants were matched by gender, age, ethnic background and their mothers' education level. Within 10 days, the participants were presented with three virtual environments projected onto a big screen (a football game, 'bird and ball' game, and snowboarding), in which the children took active and interactive part. The following instruments for the assessment of rehabilitation effects were used: test of everyday attention for children (Tea-Ch) – for attention assessment; Melbourne Assessment of unilateral upper limb function – for upper extremity function assessment; pediatric evaluation of disability inventory (PEDI) – for pediatric assessment of functional skills; and the short feedback questionnaire for children (SFQ-Child) – for self-reporting of participation and impressions. The results showed the following: (1) a statistically significant difference was observed between the groups, that is, the group with no brain injury accomplished better results; (2) a significant correlation was found between activities in VR and certain attention factors and self-care abilities; (3) no significant correlations were found between the upper extremity function assessment with the Melbourne Assessment instrument and VR outcome, but positive correlations were found between the use of virtual environment and reaching for objects; and (4) after VR, both groups demonstrated high levels of joy and high levels of control, especially in the snowboarding virtual environment, which was less demanding with respect to motor skills. The overall conclusion of the research is that there is a potential for the use of VR in the rehabilitation process in children with acquired brain injuries in the following areas: improving attention capacity and upper extremity function, and partly in encouraging self-care[11].

A positive effect of VR on improving the upper extremity function in children with cerebral palsy has been noted by Chen *et al.*[6], and positive effect on these functions in a wider range of neurological disabilities by Galvin *et al.* in their paper analyzing a number of studies by other authors[12]. Upper extremities are important for active communication with the environment[13]. Their representation in the brain takes up one-third of the entire space for the motor region. As different studies have shown, each individual finger also has a relatively high representation in the cerebral cortex[14], which points to the importance of fine motor skill development, that is to say, precise highly differentiated movements of hand musculature according to the principles of differentiation and hierarchical integration[15,16]. The development of fine motor skills in the hand is indicative for the entire development of the child, and it is also a predictor of immaturity of the central nervous system[17-20]. Matijević *et al*. have discussed frequent learning, attention and fine motor skill disabilities in preschool and schoolchildren who were born with neurodevelopmental risk, and emphasize the importance of initial compensation in the early development of graphomotor skills with the aim to prevent later difficulties in the development of graphomotor skills and writing[21].

Chen *et al.* demonstrated improvement in visual-motor performance, kinematics of object reaching, fine motor skills, measured hand function, and measured changes in neuroplasticity. Every analyzed research showed a type of improvement in motor function over a period of time after the intervention, but, according to the authors, due to the small number of participants and other methodological shortcomings, generalization of the results in the analyzed studies is limited[6,12].

Sinder *et al*. analyzed a number of studies focused on the application of VR in rehabilitation treatment for children with cerebral palsy, specifically in the areas of increasing competence and self-esteem in motor activities, which are usually not performed by these children. The authors included 13 electronic databases and analyzed articles up to 2008 in English and French, which included interventions with the help of VR for children with neurological impairments. The databases were searched using the key words (tetraplegic, spastic, monoplegic, cerebral palsy ...) and

13 studies were included in final analysis. The areas observed in these articles were brain plasticity, motor capacity (motor skills), functional everyday activities (self-care, free time activities), visual-perceptual skills, social inclusion and personal factors (motivation, self-perception). A positive effect of VR on brain plasticity, motor skills and visual-spatial outcomes was observed in 7 of 9 studies. Two studies pointed to the positive effect of VR on activities and participation, and positive effect of VR was recorded in all 5 studies that examined the effect of VR on motivation and self-perception factors[22].

Brütsch *et al.* studied the effect of football game in virtual environment in children and adolescents with neurological impairments as a motivation for walking training assisted by robotics (Robotic Assisted Gait Training, RAGT) with the use of a Lokomat electrical device (two orthoses attached to the child's legs, which are powered by two motors and in this way they move and simulate the natural gait). By means of an interface with which the sensors on the orthoses were connected to the computer, the children could move the ball while playing with the two virtual characters. The aim of this research was to compare the effects of different strategies on the muscle activity during RAGT, whereas the training itself was structured through 4 modalities: (a) non-assisted gait; (b) gait assisted by therapist; (c) gait assisted by VR; and (d) gait assisted by therapist and VR. The sample consisted of 18 children and adolescents aged 4 to 18 years (10 in the experimental group and 8 children and adolescents without difficulties in the control group). Acceptance of Lokomat and motivation was measured by using the visual analog scale. The results showed that VR had the same impact on motor skills as therapist's assistance, thereby making VR a useful instrument in ensuring the child's motivation through the application of RAGT. In both groups, improved results were recorded during VR and assistance by the therapist in comparison with the baseline study. The children without difficulties showed better results than the children with impairments, but VR proved to be a useful motivational tool for gait training with the help of RAGT in both groups[23].

The motivational factor, which is relevant for active participation in gait exercise assisted by robotics (RAGT with the help of Lokomat) and the role of therapist in the motivational process in children with locomotor impairments were also the focus of the study by Schüler *et al.* According to the authors' hypothesis, the momentary muscle effort would be higher during RAGT with VR and the added assistance by the therapist in comparison with the initial gait study without VR. The sample consisted of 9 children and adolescents aged 8 to 17 years with a range of gait impairments and 8 age-matched children and adolescents without such difficulties. Motivation was measured by using the visual analog scale and Intrinsic Motivation Inventory instrument, whereas muscle activity was monitored by electromyography during RAGT with VR (football game and games of collecting objects in open space). The results showed that the measured muscle activity was much higher in the tasks with VR and therapist's assistance in comparison to the tasks under normal conditions in both groups (except for the games in open space for the group without impairments). The results were also high for both groups with regard to maintaining interest in the task, satisfaction, and internal motivation. The results also showed that motor activities were greater in the tasks where besides VR there was also therapist's support, which indicated the importance of the child-therapist relationship as a feature of the rehabilitation process. The hypothesis was proven according to which VR and therapist's support were effective in improving motivation and encouraging motor effort and motor activities in children with locomotor impairments[24].

Conclusion

In the contemporary world, computer is a source of fun for most children and adolescents. They spend up to a couple of hours in front of the screen, which points to the fact that interactive games keep the child's attention. Besides the motivational aspect, the advantage of computer technology is that the practical element resembles real life situations and as such allows the user to make mistakes and learn in a safe environment. In this regard, VR offers a unique medium in which rehabilitation and therapeutic treatments can be offered within a functional, purposeful and motivating context, which can be readily graded and documented.

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Sažetak

VIRTUALNA STVARNOST U REHABILITACIJI I LIJEČENJU

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U radu se prikazuje opis virtualne stvarnosti i neke mogućnosti njezine primjene u rehabilitaciji i terapiji. Navedeni su neki vidovi primjene ove tehnologije u različitim problemskim područjima (senzomotorički poremećaji, autizam, teškoće u učenju), kao i neka znanstvena istraživanja u kojima su se ispitivale promjene nekih parametara motorike i motivacije vezane uz rehabilitaciju djece s motoričkim poremećajima. Naglašeni su pozitivni učinci virtualne stvarnosti kao metode u kojoj se rehabilitacijski i terapijski postupci mogu provoditi i ocjenjivati unutar funkcionalnog, planiranog i motivirajućeg konteksta.

Ključne riječi: *Virtualna realnost u terapiji; Rehabilitacija; Razvojni poremećaji; Šaka; Motoričke vještine*