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6 AUTHORS, INCLUDING:

Alin Moldoveanu

Polytechnic University of Bucharest

Florica Moldoveanu

Polytechnic University of Bucharest

Asavei Victor

Polytechnic University of Bucharest

Ionut Negoi

Carol Davila University of Medicine and Pha…

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CHALLENGES AND ISSUES FOR SUCCESSFULLY APPLYING VIRTUAL REALITY IN MEDICAL REHABILITATION

Oana-Maria FERCHE, Alin MOLDOVEANU, Florica MOLDOVEANU, Alexandra VOINEA, Victor ASAVEI
POLITEHNICA University of Bucharest, Romania
oana.ferche@cs.pub.ro, alin.moldoveanu@cs.pub.ro, florica.moldoveanu@cs.pub.ro, oana.alexandra.voinea@gmail.com, victor.asavei@cs.pub.ro

Ionuț NEGOI
General Surgery Department, Emergency Hospital of Bucharest
University of Medicine and Pharmacy Carol Davila Bucharest, Romania
negoiionut@gmail.com

***Abstract**: Out of the many uses of eLearning - one that stands out for having a potentially great impact on the quality of life of its users - is relearning physical and psychical abilities that were lost after acute illnesses or injuries through rehabilitation processes. Such disabilities are a great burden on the patient, on his caregivers, and on society. Simple everyday tasks represent a challenge and the patient must learn again gestures that seemed habitual before the accident. Amongst the various sciences and technologies that have been used in order to improve the classical rehabilitation processes, Virtual Reality seems to be one of the most promising. Virtual Reality is an emerging science in the field of rehabilitation, that is gaining more and more uses, due to its great advantages, such as stimulating movement and cerebral activity, increasing attention levels and simulation various environments that enhance the rehabilitation sessions. The fact that VR technologies are not yet used on a large scale in rehabilitation is due to certain disadvantages that are limiting its adoption in every specialized clinic or rehabilitation centre. Despite its many benefits, Virtual Reality in rehabilitation also has notable disadvantages that result from it using state of the art technology such as: cost-related issues, issues generated by the human-computer interfaces that it uses, which may seem unnatural for first time users, immersion issues may influence the quality of the rehabilitation process, and also compatibility issues between various devices may arise. Virtual Reality systems usually process large amounts of data, thus need processing and storage capacity. Also, many VR systems users reported side effects that cannot be ignored, as they may have an impact on the quality of the rehabilitation process but may also bring legal and ethical issues. In order to be widely adopted, VR rehabilitation must bring an obvious and secure improvement to the patient, creating an attractive price/benefit ratio. Also, the expectations of the patient must be aligned to the possibilities that the technology offers and the practitioners must be tutored in using such systems in order to obtain the most benefits. In this article we will review the most important disadvantages as well as analyze possible solutions for overcoming them. The solutions may be available at the present moment, or may require that the technology progresses, but the key factor seems to be cost related, as lowering the costs of VR technology would allow more users to access its features, some as end users and some as potential developers, allowing them to discover and correct the shortcomings of VR applications and devices.*

***Keywords:** Virtual Reality; Medical rehabilitation; Challenges.*

I. INTRODUCTION

Virtual Reality (VR) is a technology that has been available since the late '80 [10] and currently its application domains cover a wide range, such as:

- aviation (pilot training in virtual environments)
- education (simulations that create a feeling of "being-there" for students and educators of various fields in order to train for future real life situations), archaeology (creating replicas of existing work) or
- medicine: in the field of medicine, VR proves to add promising value to various activities, from surgical training to rehabilitation and experiments.

Physical rehabilitation is a branch of medicine that is dedicated to helping the patient re-learn behaviours and gestures that were lost as a result of an accident. This often proves to be an overwhelming task for the patient and for the clinician. A large number of repetitions of the same movement may be necessary until it is relearned and can be executed independently. This is one of the many reasons why technology and particularly Virtual Reality could be a great help in assisting the medical rehabilitation sessions: a VR environment could present the patient with an example of the correct movement that he has to execute, as well as create an interesting environment that would motivate him to continue the session without getting psychically tired or lose focus. A virtual environment is also flexible and it could be adapted to various deficiencies and personal preferences of the patient, allowing him to rehearse actions in a safe environment, thus providing less anxiety and enhancing his autonomy in real life situations [19].

Studies made in the last few decades have proved that virtual reality enhanced rehabilitation sessions are more efficient than non-immersive ones [10]. Together with telemedicine (providing medical assistance from a distance through technology), VR has the potential to deliver therapy services to patients in rural settings or therapy at home [14] for patients that would otherwise not be able to access these services. A comprehensive study of VR worlds can be found in [1].

Although VR seems to be a great potential to the rehabilitation process, VR technology developers need to consider the potential issues that can arise from implementing technology for a medical field especially where disabled people are the targeted users.

II. VIRTUAL REALITY IN REHABILITATION

Virtual Reality has the ability to create limitless scenarios using dedicated software and hardware for information transfer from the user towards the system and from the system towards the user. The system output can be transmitted using various stimuli: visual, auditory, haptic, vestibular or olfactory [26].

Visual information is usually displayed using a Head Mounted Display, a device consisting of two small displays positioned in front of each eye within special helmet or goggles. Other ways of delivering visual information in VR systems use projection systems, flat screens [26] or desktop monitors. Such displays are Oculus Rift, a virtual reality headset with low latency head tracking and stereoscopical view [www.oculus.com/rift], Google Glass, a lightweight head mounted display [www.google.com/glass] or the Fifth Dimension Technologies HMD [www.5dt.com].

Auditory system response engages the user in the virtual world can be transmitted either through dedicated headsets or using audio devices integrated to the head mounted displays (such as the Oculus Rift). Binaural audio is a technology that dates back to the 1800s that records sounds exactly as the human ears would perceive it, thus it is able to recreate the sound so that the listener were actually involved in the scene where the recording was made [27].

More complex virtual reality systems also provide haptic feedback that enables its users to experience tactile sensations therefore recreating the sense of touch through vibrations or forces. The physical sensation of resistance integrated into virtual reality instruments is called force feedback [28]. In medicine such systems that reproduce resistance are especially useful in training for surgeries, as well as in remote procedures. In rehabilitation, force feedback could prove to be very useful, as it could provide feedback to a patient undergoing treatment by simulating the presence of solid objects in the virtual environment in order to sustain reproducing daily activities. Force feedback is transmitted with the aid of haptic gloves and exoskeletons (lightweight robotics, taking the shape of human body parts to perform or assist movements) - that are mostly not affordable on a large scale - or through a joystick or steering wheel.

The enhancement of the virtual world with olfactory feedback, whose potential has not been yet thoroughly investigated is possible, but still rarely implemented [26].

As described in [26], the number of applications of VR in rehabilitation continues to grow due to various advantages it provides over traditional practices:

- It creates a safe and ecological environment for the sessions to take place in. Examples of such applications are: training patients with neglect to safely cross the street, or to assess the driving capabilities of patients following brain injury.
- VR allows control over provided stimuli and allows environmental adaptations to the performance of the patient
- Allows quantification of performance and could lead to standardization of treatment protocols, as presented in an application that assesses the cognitive function using a virtual kitchen, presented in [29] or in one that quantifies the hand functions such as range of motion of fingers after stroke [30].

III. ISSUES OF VIRTUAL REALITY IN REHABILITATION

2.1 Accomodation

The first issue with using VR for medical rehabilitation is that it needs a greater time for the patient to accommodate to the virtual reality that is very probably quite different from the reality he is accustomed to.

After having suffered a stroke, patients are most certainly in a fragile psychical state and placing them in an unknown environment, or in one that is greatly different from the natural one may produce them a great shock.

It is vital for the success of the virtual reality therapy that the patient is given time to accommodate to the VR and he is immersed gradually in order to allow him to accept it and feel comfortable in it. Another way of making the environment comfortable is by reproducing a calming, known virtual world, where the patient can feel safe, or even use augmented reality in the first sessions in order to allow the patient to understand that the environment where the sessions take place is slightly different form his known reality.

Another accommodation issue is related to the equipment necessary in order to create such a system. A head mounted display (HMD) imposes an extra weight to the head of the patient, that may take time to get accustomed to or may not even be an option as in some patients postural control muscles are also affected by the disability [20].

2.2 Transfering performance

One key issue with VR rehabilitation is pointed out in [20] and refers to the transfer of the performance obtained in the virtual reality into the real world. In this article it is stated that many studies examine learning in a virtual environment but do not asses the degree in which the achievements from the virtual world can be used in the real world, as the two are not equivalent and the discrepancies between them may affect the rehabilitation sessions in a negative way.

As cited in [20], in [21] an experiment is described where three groups of subjects were trained to move a set of cans to matching positions: one set was trained in the real world, a set was trained in a Virtual Environment (VE) and the third set received no training. The conclusion of the test was that the set of subjects trained in the VE obtained the same results in the real environment as the set that received no training, although their performance in the VE improved at the same rate as the real world trained set. The causes of this observation were related to the differences between the two environments.

In order to obtain a successful performance transfer, the actions exercised in the VE should be very well observed and represented as they should match the movement necessary in real life. Although the differences between virtual and real must be diminished, the effort should not be concentrated solely on obtaining the best possible accuracy of the real environment, as [20] states that discrepancies between the two should be assessed permanently in order to avoid improving the fidelity beyond what is necessary to obtain an efficient training session.

2.3 Maintaining motivation

Although maintaining motivation seems to be one of the advantages of using VR enhanced rehabilitation solutions, the designers of such systems must take into consideration the fact that simply providing a virtual teacher that the patient must try to imitate is not sufficient. A regular rehabilitation session - assisted by a clinician - counts on the observation of the therapist for adjusting the performed exercises.

Methods for assessing the concentration levels of the patient, as well as ways of adjusting or changing the session contents according to these observations must be included in a VR rehabilitation system. These adjustments must be made with consideration, as very complex or realistic elements present in the environment may appeal to a normal subject but may overwhelm a rehabilitation patient [20].

2.4 User interfaces

Another drawback of using VR in rehabilitation is that the existing user-interfaces are not yet very user-friendly, especially for impaired users. Navigating through a VR is usually made using a joystick, a keyboard or a wand, but as these may be easy to use for the non-impaired, they may impose problems on the patient recovering from a stroke.

The user interface must be adapted to the patient's degree of understanding of existing technology (a patient that has used a similar device pre-stroke may re-learn to use it fast, or may not even need a learning time) and to his disability, as it should not impose greater effort on the patient who must be fully concentrated to the exercises and movements that he makes during the session and not to using the given user interface.

A solution to this drawback is using 3D motion capture hardware, such as a cyber-physical system consisting of a network of sensors placed on the exercised limb, that would permanently asses its position, therefore updating the virtual world according to the actions of the patient without him making any extra effort.

The second problem imposed by the user interface is the way the virtual world is displayed to the user. The use of a desktop screen may be more familiar, but it certainly does not provide a great degree of immersion. The solution of using virtual reality glasses, that display the virtual world in 3D provides a good quality immersion but needs a greater time to get accustomed to. The patient could be given time to experiment with the display interface in a simple virtual reality before starting the rehabilitation sessions in order to acquire a greater degree of familiarity.

2.5 Usability

Another aspect that is also related to the user interfaces is that the system needs to be as easy to use as possible - some go as far as saying that "the rule of thumb should be that the menus, options, and so forth for adjusting stimulus parameters should be no more complex than that found in MS Powerpoint!"[2].

This is especially difficult as the rehabilitation process is a very complex one, many parameters need to be taken into consideration, and it also needs to provide a variety of functionality and difficulty levels in order to adapt to the real sessions, therefore obtaining these results through a very simple graphical interface is a considerable effort.

One of the main usability issues imposed by VR is generated by the complex equipment involved in such rehabilitation sessions, and by the lack of maturity of this equipment. Complex technology requires complex commands and is therefore difficult to use by the non-technical medical staff. Still in development, the VR technology has not yet reached its maturity and it has yet to achieve complete customer understanding and acceptance [32].

Another usability issue is strictly related to the use of VR technology for rehabilitation purposes and is due to the condition of its users. A disabled user may have a difficulty in re-learning to use a device that he was accustomed to before the accident and even more in getting used to a new technology and to new input devices.

Even considering usability as a priority in developing the user interaction system, there is still needed that the clinician has an end-user technical expertise, a problem that may be resolved by training the clinicians in using the system in a clinical location prior to appointing actual rehabilitation sessions.

2.6 Supervision

Even though VR rehabilitation systems have the potential to be used in a stand-alone at home environment, because they are still a relatively newly researched field, supervision by a medical professional with technical expertise is still advised thus affecting the advantage of at-home rehabilitation.

An option for remote supervision would be telemedicine - providing remote medical assistance or monitoring through existing telecommunication technologies - that would request a supplemental effort from the clinician as well as for the clinic, in order to provide and get accustomed to the required technology.

2.7 Insufficient existing research

As stated in [33], the relatively slow clinical acceptance is partly because of insufficient statistical data on efficacy and safety.

Even though there are numerous works regarding the field of VR in rehabilitation, the research teams do not always have the needed interdisciplinary degree for such complex studies, or the communication between the specialists is insufficient.

Combining the state of the art of VR with the latest information in medical rehabilitation requires both technological as well as medical knowledge. In order to obtain the desired results, the involved team must contain specialists in engineering as well doctors and they must share the latest information in both fields, which can sometimes be a challenge.

Also, each disability would require a very particular configuration, dedicated applications and specific research.

2.8 Device compatibility

VR rehabilitation is still a newly emerging field and a VR system for the disabled is a complex one, that generally includes at least a motion tracking system or another user input device, display and sound equipment, cameras, various vital parameters monitoring systems, or even a Brain Computer Interface (BCI) all connected and able to transmit information to a central system, in order for the rehabilitation session to take place safely and with the best results. Each of these components has its own interface, and standardization has not yet been achieved, thus the engineering effort of developing such a system. In many cases, it is nearly impossible to replicate the same execution environment, because of differences between various existing configurations and applications need to be able to accommodate to similar devices (graphic cards, trackers, drivers, etc.)[2].

As stated in [13], due to the lack of reference standards, most VR applications in the field can be considered "one-off" creations, tied to the hardware and software they were developed for.

2.9 Costs

There are two economic issues that must be taken into consideration: the profitability for the developer of VR rehabilitation systems and the cost for the end user.

As it is a challenge to estimate the costs of such a system, many are discouraged to tackle developing this kind of product. In order to produce an economical viable product, it is essential to have a targeted market that is as wide as possible.

We have discussed the issue of producing a flexible VR rehabilitation system that needs to adapt to different hardware configurations, but it also has to adapt to different clinical situations, a problem that is even more difficult to assess, as it needs a deep understanding of the specific rehabilitation process, and thus cannot cover all possible situations, so the targeted market is generally narrowed to one or a few specific rehabilitation session types.

The second economic issue is the cost of such systems for the end user. [33] presents a cost comparison between a possible low-end configuration of a VR system used for upper limb rehabilitation and a similar high-end system. The low-end configuration adds up to a cost of $549 and it consists of:

- Xbox computing platform
- P5 glove
- Java 3D programming toolkit
- Monitor

Meanwhile, the presented high-end alternative costs $17,800 and contains:

- PC
- CyberGlove – a motion capture data glove with numerous joint-angle measurements that accurately aquires finger motion information and transforms it in real time in joint-angle data [34] with costs estimated to $10,000
- WorldToolKit – a library of over 1000 functions that enable programmers to develop new virtual reality applications [35]
- Monitor.

While the cost comparison of the two configuration is favorable in terms of cost to the low-end one, lower costs also imply lower performance. The P5 glove cannot measure the individual joints of each finger and has less accuracy than the CyberGlove. An even more expensive alternative would have been the Rutgers Master II glove that can also provide force feedback [33].

Although there are experiments that test the possibility of developing a VR rehabilitation system using more affordable devices such as Play Station II [16], a Wii console [18] or a Kinect [22] the prices for a full software and hardware commercial and immersive system can reach tens of thousands of dollars, and therefore, even if this would be acceptable for departments or hospitals it is still unaffordable for a single user [13].

2.10 Ethical issues

Besides the engineering issues, using VR in rehabilitation processes also imposes legal and ethical issues.

Ethical issues [6] are mainly related to the confidentiality of the information acquired during the sessions. If the system uses communication over a network in order to transmit information about a patient, all the data must be secured by using an encryption algorithm. The patient or his guardians must be informed regarding the threats of transmitting and manipulating electronic information and regarding the system users that will have access to his information, how long this information is going to be stored and about the degree of success the technology can obtain.

The system also needs to provide authentication, in order to supervise that the provided information is accurate.

Establishing if virtual reality assisted rehabilitation is a viable solution for the patient is also an ethical issue, and the decision must be based on a very well established set of guidelines. Several aspects must be analyzed beforehand, such as: if the patient is able to understand and accept the virtual world, to adapt to the interfaces, if the patient is able to inform the clinician of any discomfort, and lastly if during the sessions he responds to the augmented therapy better than to classical rehabilitation sessions or if he experiences any side effects.

Another ethical issue is related to how will the doctors be certified to use virtual reality, as they need to have experience with VR systems, must understand the benefits as well as the risks of exposing a patient to the virtual environment and to be able to react to any circumstance involving the procedure.

2.11 Side effects

In [20] it is stated that there seem to be no reports of negative side-effects from using a desktop version of a virtual reality system, and most of them are associated to immersive technologies created usually with head mounted displays.

The possible side effects of the virtual reality therapy must be explained to the patient and to its tutors previously to starting the sessions and the therapy must be halted if any of them are present.

According to [2], “Two general categories of VE-related side effects have been reported: cybersickness and aftereffects.” The term cybersickness was coined by McCauley and Sharkley in 1992, and it is used to describe a phenomenon similar to motion sickness that appears as a result of being immersed in a moving virtual environment while remaining physically stationary.

The symptoms of cybersickness are reported to include nausea, vomiting, eyestrain, disorientation, ataxia, and vertigo [7]. The after effects are generally due to the fact that the subject has adapted to the virtual world sensory and motor requirements and needs time to return to the real world ones.

The symptoms of after effects may include "disturbed locomotion, changes in postural control, perceptual-motor disturbances, past pointing, flashbacks, drowsiness, fatigue, and generally lowered arousal" [8].

2.12 Legal issues

The legal issues that must be taken into consideration regard the currently applicable laws in the field of personal information, confidentiality, medicine and rehabilitation in the country where the system is used. Some of these issues generally concern [6]:

- informed consent – the patient, his legal guardian or other authorized party must be informed regarding the process, its potential risks, benefits and alternatives and he must provide his consent
- standard procedures – the clinician must also follow the standard procedure of the rehabilitation process when using Virtual Reality, the purpose of the technological system is to enhance the session, not to alter its fundaments
- emergencies – the procedure in case of emergency must be very well established and in case it was related to the enhancements of the VR technology, the patient must revert to the classical rehabilitation sessions.

Another legal aspect that must be taken into consideration is that related to the potential lawsuits that may come from the doctor, researcher, developer or institution being held responsible for injuries the patient suffered as a result of after effects of the VR session [2]. According to [9], safety precautions that can be taken include: "1) Systems should be properly designed; 2) Aftereffects should be removed, guarded against, or warned against; 3) Adaptation methods should be developed; 4) Users should be certified to be at their pre-exposure levels; 5) Users should be monitored and debriefed" (p. 543).

IV. CONCLUSIONS

In this article we reviewed the available documentation regarding the potential issues that must be considered by researchers and developers that activate in the field of VR rehabilitation. We discovered issues regarding the accommodation of the patient to the technology as well as related to the necessity of a training period for the clinicians, the need for more research in the field with improved interdisciplinary collaboration as well as more affordable solutions that would allow the patient to benefit from the virtual environment benefits at home. Side effects have been proven to appear in certain configurations and the system must be developed with regard to several ethical and legal issues.

We can conclude that, despite the existence of several downsides, the therapeutic effects of using VR in rehabilitation must be empirically investigated for an evidence-based practice but the benefits discovered so far prove it to be an area worthy of further research [14].

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Reference Text and Citations

[1] A. Moldoveanu, F. Moldoveanu, V. Asavei, C. Boiangiu. Realitatea Virtuala. Ed MatrixRom, ISBN 973-755-488-8, 216 pg. 2009.

[2] A. Rizzo, G. Kim, 2005. A SWOT Analysis of the Field of Virtual Reality Rehabilitation and Therapy, *Massachusetts Institute of Technology*. Presence, Vol. 14, No. 2, April 2005, 119–146.

[3] D. Meldrum, S. Herdman, R. Moloney, D. Murray, D. Duffy, K. Malone, H. French, S. Hone, R. Conroy and R. McConn-Walsh. Effectiveness of conventional versus virtual reality based vestibular rehabilitation in the treatment of dizziness,

gait and balance impairment in adults with unilateral peripheral vestibular loss: a randomised controlled trial. BMC Ear, Nose and Throat Disorders 2012, 12:3.
[4] D. Jack, R. Boian, A. Merians, M. Tremaine, G. Burdea, S. Adamovich, M. Recce, H. Poizner, 2001. Virtual Reality-Enhanced Stroke Rehabilitation. IEEE transactions on neural systems and rehabilitation engineering, vol. 9, no. 3, september 2001.
[5] A. Merians, D. Jack, R. Boian, M. Tremaine, G. Burdea, S. Adamovich, M. Recce, H. Poizner, 2002. Virtual Reality–Augmented Rehabilitation for Patients Following Stroke. Physical Therapy . Volume 82 . Number 9 . September 2002.
[6] M. Manhal-Baugus, 2001. E-Therapy: Practical, Ethical, and Legal Issues. Cyberpsychology & Behavior Volume 4, Number 5, 2001 Mary Ann Liebert, Inc.
[7] R. S. Kennedy, K. S. Berbaum, J. Drexler ,1994. Methodological and measurement issues for identification of engineering features contributing to virtual reality sickness. Paper presented at Image 7 Conference, Tucson, AZ.
[8] J. P. Rolland, F. A. Biocca, T. Barlow, A. Kancherla, 1995. Quantification of adaptation to virtual-eye location in see-thru head-mounted displays. Proceedings of the IEEE Virtual Reality Annual International Symposium '95 (pp. 55–66). Los Alamitos, CA: IEEE Computer Society Press.
[9] R. S. Kennedy, K. E. Kennedy, K. M. Bartlett, 2002. Virtual environments and product liability. In K. Stanney (Ed.), Handbook of virtual environments (pp. 534–554). New York: Erlbaum.
[10] Man, D.W.K. (2010). Common Issues of Virtual Reality in Neuro-Rehabilitation, Virtual Reality, Prof. Jae-Jin Kim (Ed.), ISBN: 978-953-307-518-1, InTech, Available from: http://www.intechopen.com/books/virtualreality/ common-issues-of-virtual-reality-in-neuro-rehabilitation
[11] G. Burdea. 2002. Key Note Address: Virtual Rehabilitation-Benefits and Challenges.
[12] J. Liepert, H. Bauder, W. Miltner, E. Taub, C. Weiller. 2000. Treatment-Induced Cortical Reorganization After Stroke in Humans.
[13] G. Riva. 2000. Virtual Reality in Rehabilitation of Spinal Cord Injuries: A Case Report. "Rehabilitation Psychology", 45 (1), 1-8, 2000
[14] J. Halton. Virtual rehabilitation with video games: A new frontier for occupational therapy.
[15] F. D. Rose, B. Brooks, A. Rizzo. 2005. Virtual Reality in Brain Damage Rehabilitation: Review. CyberPsychology & Behaviour. Volume 8, Number 3, 2005. © Mary Ann Liebert, Inc.
[16] D. Rand, R. Kizony, P. L. Weiss. 2004. Virtual reality rehabilitation for all: Vivid GX versus Sony PlayStation II EyeToyProc. 5th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Oxford, UK, 2004 ICDVRAT/University of Reading, UK; ISBN 07 049 11 44 2
[17] G. Burdea, V. Popescu, V. Hentz, K. Colbert. 2000. Virtual Reality-Based Orthopedic Telerehabilitation. IEEE Transactions On Rehabilitation Engineering, Vol. 8, No. 3, September 2000.
[18] J. Deutsch, M. Borbely, J. Filler, K. Huhn, P. Guarrera-Bowlby. 2008. Use of a Low-Cost, Commercially Available Gaming Console (Wii) for Rehabilitation of an Adolescent With Cerebral Palsy. Physical Therapy, Vol. 88, No. 10, October 2008.
[19] G. Riva, B. Wiederhold. 2006. Emerging Trends in CyberTherapy Introduction to the Special Issue. PsychNology Journal, Vol. 4, No. 2, pp. 121-128, 2006.
[20] M. Holden, E. Todorov. 2002. Use of Virtual Environments in Motor Learning and Rehabilitation. Handbook of Virtual Environments: Design, Implementation, and Applications, Ch. 49, 2002.
[21] Kozak, J.J., Hancock, P.A., Arthur, E.J., & Chrysler, S.T. (1993). Transfer of training from virtual reality. Ergonomics, 36, 777-784.
[22] Virtual Reality Kinect Rehabilitation: SeeMe Rehabilitation. Feb. 2014. [http://www.virtual-reality-rehabilitation.com/products/seeme/what-is-seeme]
[23] M. Dascalu, A. Moldoveanu, E. Ahmad Shudayfat. Mixed Reality to Support New Learning Paradigms. Proceedings of the 18th International Conference on System Theory, Control and Computing, Sinaia, Romania, October 17-19, 2014, pp. 698-703, ISBN 978-1-4799-4602-0 ©2014 IEEE
[24] M. Dascalu, A. Moldoveanu, G. Dragoi, O. Balan, Understanding and Improving the Usage And Impact Of E-Learning In Medical Education, Proceedings of the ICERI Conference, Seville, Spain, November 17-19, 2014, pp. 6574-6580
[25] M. Dascalu, G. Dragoi, N. Stroescu, A. Moldoveanu. Semantic Collaborative Task Management Tool with Social Media Integration. Knowledge-Based Software Engineering - Communications in Computer and Information Science (CCIS), vol. 466, eds. A. Kravets et al., CCIS 466, Springer International Publishing Switzerland 2014, pp. 214–227. ISBN 978-3-319-11853-6, Online ISBN 978-3-319-11854-3, ISSN: 1865-0929. 2014.
[26] P. Weiss, R. Kizony, U. Feintuch, N. Katz. 2005. Virtual reality in neurorehabilitation. p. 182-197.
[27] http://www.polygon.com/2015/2/12/8028379/binaural-3d-audio-virtual-reality-oculus-rift-project-morpheus, last accessed 02/2015.
[28] http://medical-dictionary.thefreedictionary.com/, last accessed 02/2015
[29] Christiansen, C., Abreu, B., Ottenbacher, K., Huffman, K., Masel, B. and Culpepper, R. (1998). Task performance in virtual environments used for cognitive rehabilitation after traumatic brain injury. Arch Phys Med Rehabil, 79, 888–892
[30] Jack, D., Boian, R., Merians, A., Tremaine, M., Burdea, G.C., Adamovich, S.V., Recce, M. and Poizner, H. (2001). Virtual reality-enhanced stroke rehabilitation. IEEE Trans Neural Syst Rehabil Eng, 9, 308–318.
[31] F. Brooks. What's Real About Virtual Reality? 1999. University of North Carolina at Chapel Hill.
[32] Virtual Reality on a path to maturity. http://www.simpublica.com/technology/virtual-reality-on-a-path-to-maturity/. Last accessed 02/2015.
[33] K. Morrow, C. DOcan, G. Burdea, A. Merians. Low-cost Virtual Rehabilitation of the Hand for Patients Post-Stroke. 2006. International Workshop on Virtual Rehabilitation, New York, NY. ISBN 1-4244-0280-8.
[34] GyberGlove Systems. http://www.cyberglovesystems.com/products/cyberglove-II/overview. Last accessed 02/2015.
[35] WorldToolKit Reference Manual. http://www.cs.princeton.edu/courses/archive/spr01/cs598b/papers/wtkr9.pdf. Last accessed 02/2015.