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Effectiveness of Virtual Reality Therapy in Patients with Neurological Disorders

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KEYWORDS

virtual reality, neurological disorders, virtual reality therapy, stroke,VRT, CP

ABSTRACT:

Background: Recent advancements in Virtual Reality (VR) provide new tools for the development of novel and promising applications for rehabilitation in various neurological disorders. The purpose of this review is to the emerging VR applications developed for the evaluation and treatment of patients with neurological diseases and discussing the impact of novel VR tasks that encourage and facilitate the patient's empowerment and involvement in the rehabilitation process. Overall, this review explains the evolution of use of the VR in both adults and paediatric neurological conditions such as stroke, spinal cord injury, Parkinson's, Traumatic brain injury, multiple sclerosis, cerebral palsy, Down syndrome, Guillian barre syndrome, autism and muscular dystrophy.

Methodology: The review search retrieved 192 citations which represented 146 studies. A total of 89 studies were included in the literature review and among them 56 studies for adult's population and 33 studies for paediatrics' population.Two high-quality databases (Pub Med and Web of Science) were used to perform the search. Keywords used for each separate string were ("virtual reality" OR "virtual") AND ("neurorehabilitation" OR "rehabilitation" AND ("balance and gait disability" OR "upper extremity functions" OR "cognitive impairments" OR "neuropathic pain") and were search through Title/Abstract and Topic for each database, respectively, over the last twenty-five years (2003–2020).

Result: Most of the studies reveal positive results suggesting that VR is a feasible and effective tool in the treatment of neurological disorders. In addition, the development of VR technologies in recent years has resulted in more accessible and affordable solutions that can still provide promising results.

Conclusion: VR and interactive devices resulted in the development of holistic, portable, accessible, and usable systems for certain neurological disease interventions. It is expected that emerging VR technologies and tools will further facilitate the development of state of the art applications in the future, exerting a significant impact on the well being of the patient.

Introduction

Virtual reality has been defined as ‘‘the utilization of intelligent recreations made with computer software and hardware to introduce the individual who are utilizing, with freedoms to participate with opportunities to engage in environments that feel and appear similar to real-world objects and events’’. In virtual rehabilitation, virtual environments and objects provide the user with visual feedback, which may be presented though a projection system, flat screen or head-mounted device and feedback may also be provided through the senses (hearing, touch, movement and balance). [1]

virtual reality as a closed computer system that consists of a virtual environment, a physical environment, as well as a software and hardware interface, which allows interaction between a human and a computer. [2] Virtual

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reality, which is described to be a medium composed of interactive computer simulations. In such a medium, the user's, or participant's, position and actions are sensed in order to replace or augment the feedback to one or more senses.[3] This approach gives the feeling of being mentally immersed in the simulation or virtual world. A very recent, yet comprehensive, definition was introduced by the authors, who refer to virtual reality as ''computer-generated simulations of three-dimensional objects or environments with seemingly real, direct, or physical user interaction. [4]

There are four key elements of a virtual reality experience; these are virtual world or medium, immersion, sensory feedback, and interactivity.[3] There are three types of VR systems are available. These are (i) Non-immersive VR systems, is a desktop computer based 3D graphical system which allows the user to navigate the Virtual environment that is displayed on a computer screen, typically with the keyboard and the mouse; (ii) Semi-immersive systems project the graphical display onto a large screen, and may rely on some forms of gesture recognition system to implement more natural interactions; (iii) Fully-immersive systems in which the users' vision is fully enveloped, creating a sense of full immersion via a head-mounted display (HMD) [5]

Neurological diseases frequently cause adult-onset disability and have increased the demand for rehabilitative interventions. Neurorehabilitation has been progressively relying on computer-assisted programs and, more recently, on virtual reality (VR). Current reviews explore VR-based neurorehabilitation for assessing and treating the most common neurological pathologies.[6] A lot of individuals worldwide have influenced with Neurological issues portrayed by impeded capacity which causes decreased day by day work, reduced daily living function, and has a negative impact on quality of life. In the restoration programmes might be offered to people with such troubles, to improve capacities in exercises of everyday living and increment social support and regularly conveyed to patients with a scope of conditions incorporating patients living with stroke or spinal cord injury (SCI). Joining conventional recovery procedures with the utilization of new innovations (for example brain- computer interfaces, wearable gadgets, neuroprosthetic devices, non-invasive brain triggers and robotic movement for examination) may emphatically effect on recovery of intellectual elements of patients. A captivating (arising) and novel opportunities for recovery of neurological issues in people may lie in the utilization of computer generated reality (VR). [7]

Virtual reality systems (VRS) are most normally utilized in paediatrics recovery program. Paediatrics recovery covers a wide scope of uses and incorporates medicines for different problems, like children with orthopaedics, neurological and developmental or formative incapacities. Child with neurocognitive or neurologic weaknesses may encounter diminished working in different spaces including: physical, passionate or intellectual and psychosocial and such disabilities address critical impediments in exercises of everyday life of the child. [8] Children may experience are carried out through a joint investigation of numerous orders in restoration program to treatment, everything being equal, and the VR can be use via trained therapist empowers to adapt to these hindrances.[9] VR conceivably offers children with incapacities the chance to take part in games in any case difficult to reach. It offers 3D spatial the level of the development between this present reality and the computer. Children can likewise rehearse seriously and at the same time get positive visual, proprioceptive, material and hearable sense inputs in VR.[10,11] The utilization of it in young children with incapacities gives motor learning, postural and motor control and improves sensorial-perceptual-motor-cognitive-communication abilities. So children become more autonomous people in their day-today lives.[12] There are numerous benefits show in the utilization of VR for paediatrics restoration. Initially, VR is a goal-directed strategy which can be utilized for preparing and instruction to increment of abilities like motor, perception, sense, psychological and social in children.[13] Besides, it was persuasive, utilitarian and a good time for children. So that, it is perhaps the most favoured treatment strategies for the children and the therapists.[14]

New technological advancements have paved the way for the emergence of a novel approach for human rehabilitation. Particularly computer-assisted neurorehabilitation has shown several advantages such as individualized, flexible, and economical programs

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providing immediate feedback. This form of rehabilitation employs technologies such as robots, non-invasive brain stimulation, wearable systems and neuroprosthetics. Among these VR shows great promise and intriguing possibilities for neurorehabilitation.[6] In recent years, VR technologies have begun to be used as an assessment and treatment tool in rehabilitation. The rationale for using VR in rehabilitation is based on a number of unique attributes of this technology. These include the opportunity for experiential, active learning which encourages and motivates the participants. In addition, there is the ability to objectively measure behavior in challenging but safe and ecologically valid environments, while maintaining strict experimental control over stimulus delivery and measurement. VR also offers the capacity to individualize treatment needs, while providing increased standardization of assessment and retraining protocols. Virtual environments provide the opportunity for repeated learning trials and offer the capacity to gradually increase the complexity of tasks while decreasing the support and feedback provided by the therapist. Moreover, the automated nature of stimulus delivery within virtual environments enables a therapist to focus on the provision of maximum physical support when needed without detracting from the complexity of the task.[15] Using technology becomes an integral part of daily living and virtual reality is likely to become even more widely used tool in clinical rehabilitation settings. So, this study is conducted to evaluate the efficacy of virtual reality in order to guide future design and use in rehabilitation for various neurological disorders in both adults and paediatrics filed.

Literature Review

Articles on effectiveness of VRT in improving gait and balance in various adults and pediatrics neurological disorders

Studies title (years)	**Outcome measures**	**Results summary**
Madhusree Sengupta et al [16] 2020	Semi-immersive VR therapy along with conventional therapy and Tinetti Performance-Oriented Mobility Assessment (POMA-B), Berg Balance Scale (BBS) and Functional Reach Score (FRS) were used for assess balance improvement.	VR has a beneficial effect on balance rehabilitation in patients with SCI
Myung Joon Kim et al[17] 2020	Virtual reality treadmill training and spatiotemporal parameters analyze by gait analyzer.	Community-based VRGT has been shown to improve the walking ability of chronic stroke patients and is expected to be used in rehabilitation of stroke patients .
Cagla Ozkul et al [18] 2020,	.Immersive virtual reality therapy and Timed Up and Go (TUG), Berg Balance Scale (BBS), Fatigue Severity Scale (FSS) , posturography were use for assess balance improvement in pre and post treatment.	IVR training has beneficial effects to improve mobility, balance,and fatigue in patients with MS.

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Mohamed Abd El et al [19] 2017	Wii balance programme and berg balance scale use for assess improvement.	Wii games based balance training has the potential to improve the functional balance in children with Down syndrome.
Maria Alvarez et al [20] 2016	Xbox Kinect game exercise program and Unified Parkinson Disease Rating Scale (UPDRS)& Tinnetti Scale for Gait and Balance (TGB) at week 4 and 8 assess the improvement.	Motor abnormalities and gait dysfunction improved in patients with Parkinsons diseases utilizing Xbox Kinect exercise as demonstrated by improvements in UPDRS and TGB outcomes.
Devrim Tarakci et al [21] 2015	Nintendo Wii Fit games with NDT and berg balance scale use for assess the improvement.	Wii-fit balance based video games are beneficial at improving both static and performance-related balance parameters when combined with NDT treatment in patients with mild CP.
Jeffrey P et al [22] 2014	Wii Fit and Wii Sport interactive games in addition to their standard physical therapy regimen and berg balance scale for assess balance pre and post treatment.	There are evidence to support using commercially available VR gaming systems in rehabilitation for the treatment of balance deficits in patients with TBI

Articles on effectiveness of VRT in improving cognitive impairments in various adults and pediatrics neurological disorders

Studies title (years)	**Outcome measures**	**Results summary**
Tamilselvi Dhamodharan Manju et al [23] 2020	virtual reality based interactive environment and Mini Mental State Examination (MMSE), Clock Drawing Test were used to assess improvement	VR Therapy promising improvement over the behavior in the virtual interactive environment and enhance their cognitive rehabilitation in children with autism.
Rosaria De Luca et al [24] 2019	VRT with BTs-Nirvana and specific psychometric battery use to assess improvement	VR may be a useful and effective approach, leading to better cognitive and behavioural outcomes in the rehabilitation of patients with TBI.
Dong-Rae Cho et al [25] 2019	virtual reality training, including Head Mount Display with computerized cognitive therapy and the Loewenstein Occupational Therapy Cognitive Assessment and	Virtual reality immersive training might be an affordable approach for cognitive function and activity of daily living performance recovery

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	Computerized Neurocognitive Function Test for cognitive function, and Functional Independent Measure for activities of daily living were used.	for patients with acute stroke.
Giuseppa Maresca et al[26] 2018	Standard cognitive training and conventional physiotherapy combined with virtual reality training and specific psychometric battery use to assess improvement	The VRT, shows a huge improvement in various intellectual areas, a prominent decrease of nervousness and burdensome manifestations, just as motor execution, and balance improvement in quiet with SCI.
Pietro Cipresso et al [27] 2014	Mini Mental State Examination (MMSE), Clock Drawing Test, and Tower of London test, The Virtual Multiple Errands Test (VMET) were use to assess improvement pre and post treatment.	Patients huge contrasts in the VMET scores between the PD-NC patients versus PD-MCI. This VMET result is by all accounts more touchy in the early recognition of executive functions in PD patients.

Effectiveness of VRT in improving upper extremity functions in various adults and pediatrics neurological disorders

Studies title (years)	Outcome measures	Results summery
Jiri Keller et al [28] 2020	Virtual anatomical interactivity (VAI) therapy and three-jaw chuck pinch, hand key pinch strength and grasp and active range of motion of the shoulder, elbow, and wrist were used to assess muscle strength .	Virtual anatomical interactivity therapy improved motor skills and function in the affected upper extremities of subjects with traumatic brain injuries.
Ebrahim Norouzi et al [29] 2020	Virtual reality training (VRT) and Bimanual coordination was assessed by Fugl-Meyer Assessment (FMA) pre and post treatment.	Combined virtual reality and physical training improved the bimanual coordination of women with multiple sclerosis.
Ayşe Resa Aydın et al [30] 2020	virtual reality therapy and Action Research Arm Test were used to assess hand function.	VR therapy is beneficial in improving upper extremity function in CP patients.
Marta Sylvia Del Rio Guerra et al [31] 2019	The virtual reality tasks using the Oculus Rift and Fugl-Meyer Assessment (FMA) and Motor Activity Log, Functional Independence Measure and	Hand gestures in virtual and augmented 3D environments for Down syndrome consider to be effective in improving

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	Action Research Arm Test were used to assess hand function.	upper extremity functions.
Judith J. W. van Beek et al [32] 2019	Exergaming, video game-based training with Augmented virtual reality and Dexterity Questionnaire-24 and the Nine-Hole Peg Test were used to assess hand function.	Exergaming is effective to improve dexterity of upper limb in the patients with PD
Chan Wai Yin et al [33] 2014	VR therapy and Fugl-Meyer Assessment (FMA) and Motor Activity Log, Functional Independence Measure and Action Research Arm Test were used to assess hand function.	VR training with conventional therapy is beneficial to improve upper limb functions in early stroke.

Methodology of study

This review has explored the use of VR in the assessment and treatment of the most common neurological pathologies. Specifically, the use of VR in the Neuro-rehabilitation of neurological diseases in adults such as stroke, spinal cord injury, Parkinson's, GBS and multiple sclerosis as well as in paediatrics such as CP, Down syndrome, autism, muscular dystrophy etc.

Search strategy

This review search retrieved 192 citations which represented 146 studies. A total of 89 studies were included in the literature review and among them 56 studies for adult's population and 33 studies for paediatrics' population.

Two high-quality databases (Pub Med and Web of Science) were used to perform the search. Keywords used for each separate string were ("virtual reality" OR "virtual") AND ("neurorehabilitation" OR "rehabilitation" AND ("balance and gait disability" OR "upper extremity functions" OR "cognitive impairments" OR "neuropathic pain") and were search through Title/Abstract and Topic for each database, respectively, over the last twenty-five years (1995–2020). Inclusion criteria were: 1) neurological diseases including both adults and paediatrics 2) studies include which had conducted regarding effectiveness of VRT in neurorehabilitation from the year 2003 to 2020 3) studies which uses non, semi- or fully-immersive VRT in neurorehabilitation 4) studies assessing neurological evaluation pre and post VR intervention. Exclusion criteria were: 1) single case studies 2) review and research protocols 3) abstracts, conference proceedings, notes, case reports, letters to the editor, patents, and other editorial materials 4) studies in which VRT use in orthopaedics, sports, or any cardiac conditions (5) studies regarding effectiveness of VRT in neurorehabilitation before the year 2003.

Results and discussion

Almost all the studies randomly assigned patients to either an Experimental Group (EG), which consisting in VR intervention, Wii Fit and Wii Sport interactive games, Xbox Kinect sensor, VRT with BTs-Nirvana, VR social cognition therapy or a Control Group (CG) which consisted in traditional exercise therapy, no treatment, computer cognitive therapy, standard occupational therapy, conventional cognitive training, NDT, cognitive behavioural therapy, standard occupational therapy has been applied. Most of the studies show effectiveness of VRT in all impairments like balance and gait disability, upper extremity functions, cognitive impairments, neuropathic pain over the traditional or conventional treatments. However, there is less studies specifically focus on cognitive impairments and neuropathic pain but it shows that VRT is effective in improving cognitive impairments like memory in Parkinson's disease, executive functions

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in TBI and neuropathic pain in SCI patients etc. Furthermore, in case of autism & Down syndrome most studies specifically focus on cognitive impairments and in case of CP & Muscular dystrophy mainly focus on balance and gait disability and it shows that VRT is effective in improving motor functions as well as cognitive impairments in paediatric neurological disorders. Various studies regarding use of VR in neurorehabilitation for different neurological conditions of adults and children are in last 15 years in order to define their effectiveness and studies have conducted populations with CP, stroke, SCI and among other various diseases. Most of the studies were conducted with post stroke patients and it hypothesize that due to the high incidence in developed countries the stroke has been predominantly investigated (affecting 1/500 individuals every year). After stroke, CP was the most contemplated neurological problem in VR restoration. Recent study showed that VR rehabilitation programs focused on strength , balance, motor control, and gait are, overall, more effective than traditional rehabilitation programs.

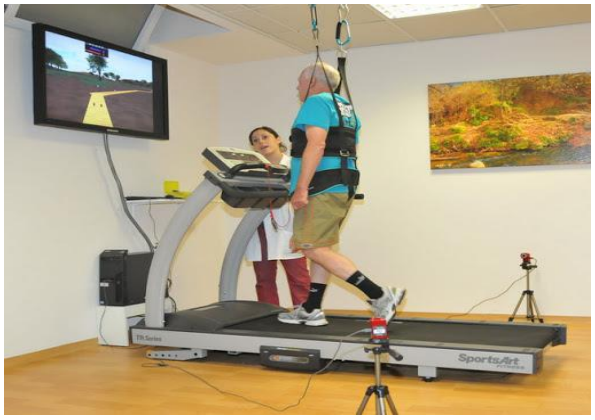

Figure 1-virtual reality therapy with treadmill training in improving gait and balance

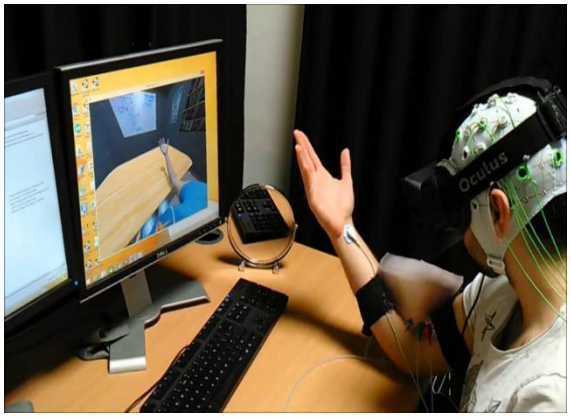

Figure 2 - virtual reality in improving cognitive impairment by giving neurofeedback

Research Gap

In spite of the increasing eagerness for VRT and collaboration of its use in clinical applications, in this literature has highlighted some gaps of research:

Various types of VR tools have been individually experimented and highlighted their effects. There is a lack of study regarding the distinction between different forms of technology might not be appreciated by clinicians, researchers, or even the general public and clear definitions of the terminology to avoid potential confusion across different types of inter active technologies, which may have different applications. Moreover, most of the neurological diseases like stroke, Parkinson's diseases, and multiple sclerosis are more common in elderly. Psychological component is more predominant and has significant effect on improving functional activities in older aged group people. There is lack of literature in VR therapy addressing the psychological component in older aged group people. Furthermore, utilizing VR offers a broad view for the therapists. Although, innovatively improves rehabilitation-based games or applications to accomplish completely versatile and client-special recovery designs are use in pediatrics neurorehabilitation now a days, however there is shortage of proof in the field of pediatrics restoration. VR could act as a non-invasive adjunct analgesic technique to current pain perception/management. Various reviews demonstrated the efficacy of this type of therapy in burn pain and procedural pain. However, an area that still needs further research is phantom limb pain, as the available reviews are mostly limited to case studies.

Conclusion

VR and interactive devices resulted in the development of holistic, portable, accessible, and usable systems for

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certain neurological disease interventions. It is expected that emerging VR technologies and tools will further facilitate the development of state of the art applications in the future, exerting a significant impact on the well being of the patient. The purpose of this research work was to carry out for emerging VR applications developed over the last few years, covering certain neurological diseases and it showed positive and promising results of using VR for rehabilitation exercise. Finally this review indicated that VR technology could be effective in improving the condition of the patient for certain neurological diseases. It is expected that VR applications in healthcare will flourish within the next few years, triggering further investigations in different clinical settings and could also prove to have an impact on the wellness of the patient.

Conflict of interest: There does not arise any conflict of interest

Reference

1. Weiss P, Kizony R, Feintuch U, Katz N (2006) Virtual reality in neurorehabilitation : 182- 97 Section A2 - Therapeutic technology
2. Muhanna A. Muhanna K. (2015) Virtual reality and the CAVE: Taxonomy, interaction challenges and research directions, Journal of King Saud University – Computer and Information Sciences 27, 344–361
3. Sherman W.R., Craig A.B., (2003) Understanding Virtual Reality: Interface, Application, and Design, First ed. Morgan Kaufmann Publishers .
4. Dioniso J.D., Burns III, W.G., Gilbert, R. (2013) 3D virtual worlds and the metaverse: current status and future possibilities. ACM Comput. Survey. 45
5. Ma M., Zheng, H. (2011) "Virtual reality and serious games in healthcare," in Advanced Computational Intelligence Paradigms in Healthcare, 169–192. Doi: 10.1007/978-3-642-17824-5_9
6. Giuseppe R. ,Valentina M. , Silvia C. and Chiara S.B.,(2020) Virtual reality in neurorehabilitation: a review of its effects on multiple cognitive domains,,Applied Technology for Neuro-Psychology Lab, https://doi.org/10.1080/17434440.2020.1825939
7. Massetti T., Silva da T. D., Crocetta T. B., (2018) The Clinical Utility of Virtual Reality in Neurorehabilitation: A Systematic Review,. Journal of Central Nervous System Disease, Volume 10: 1–18
8. Halton J., Virtual rehabilitation with video games, (2008), A new frontier for occupational therapy; 9(6):12-14
9. Chen Y.P., Lee S.Y., Howard A.M. (2014) Effect of virtual reality on upper extremity function in children with cerebral palsy: A meta-analysis. , Pediatric Physical Therapy; 26(3):289-300
10. Holden MK. (2005) Virtual environments for motor rehabilitation: Review. , Cyberpsychology and behaviour; 8(3):187-211
11. Wuang Y.P., Chiang C.S., Su C.Y., Wang C.C., (2011) Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome. , Research in Developmental Disabilities; 32(1):312-321
12. Gunel MK, Kara OK, Ozal C, Turker D., (2014) Virtual Reality in Rehabilitation of Children with Cerebral Palsy, Cerebral Palsy - Challenges for the Future,
13. Gabyzon ME, Engel YB., Tresser S, (2016) Using a virtual reality game to assess goal-directed hand movements in children: A pilot feasibility study, Technology and Health Care; 24(1):11-19
14. Harris K, Reid D., (2005) The influence of virtual reality play on children's motivation., Canadian Journal of Occupational Therapy; 72(1):21-29
15. Weiss P. L. , Kizony R. , Feintuch U. and Katz N., (2006) Virtual reality in neurorehabilitation, Selzer 2-13.qxd
16. Sengupta M. , Gupta A., Khanna M., (2019) Role of Virtual Reality in Balance Training in Patients with Spinal Cord Injury: A Prospective Comparative Pre-Post Study, 2020 ; Asian spinal Journal 14(1):51-58. Doi: 10.31616/asj..0013.
17. Kim M.J., (2020) Virtual Reality Community Gait Training Using a 360° Image Improves Gait Ability in Chronic Stroke Patients, The journal of Korean physical therapy; 32(3):186-192, DOI:10.18857/jkpt.2020.32.3.186
18. Ozkula C., Gunduza A.G., Yazicia G., Guzela A.G., Irkec C., (2020) ,Effect of immersive virtual reality on balance, mobility, and fatigue in patients with multiple sclerosis: A single-blinded randomized controlled trial, European journal of integrative medicine,

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www.jchr.org

JCHR (2024) 14(2), 2086-2094 | ISSN:2251-6727

35(9313):101092,DOI:10.1016/j.eujim.2020.101092

19. Ali M.E., (2020) Virtual Reality versus Task-oriented for Gait in CP, U.S. National library of medicine, NCT04533789
20. Alvarez M., (2016) Effect of virtual reality therapy in improving motor abnormality and gait dysfunction in Parkinson's disease,
21. Tarakci D., Huseyinsinoglu B.E., Tarakci E., Ozdincler A.E., (2015) The effects of Nintendo Wii-fit video games on balance in children with mild cerebral palsy, Official journal of japan paediatric society, 58(10):1042-1050. Doi: 10.1111/2015ped.12942
22. Cuthbert J.P., Staniszewski K., Hays K., Gerber D., Natale A., (2014) Virtual reality-based therapy for the treatment of balance deficits in patients receiving inpatient rehabilitation for traumatic brain injury,Journal of brain injury; 28(2):181-8. Doi: 10.3109/02699052.2013.860475
23. Manju T.D., Sathiyaprakash T., Karthikeyan R., (2020) Cognitive Rehabilitation for Autism Children Mental Status Observation Using Virtual Reality Based Interactive Environment, , International Conference on Intelligent Human Systems Integration pp 1213-1218
24. Luca R.D. , Leonardi S., Portaro S., Cause M.L., (2019) Innovative use of virtual reality in autism spectrum disorder: A case-study, ; journal of applied neuropsychology child, 10(1):90-100.doi:10.1080/21622965.2019.1610964
25. Ch D.R., Lee S.H., (2019) Effects of virtual reality immersive training with computerized cognitive training on cognitive function and activities of daily living performance in patients with acute stage stroke a preliminary randomized controlled trial, Journal of medicine; 98(11):e14752. Doi: 10.1097/MD.0000000000014752.
26. Maresca G., Maggio M.G., Buda A., (2018) A novel use of virtual reality in the treatment of cognitive and motor deficit in spinal cord injury A case report,Journal of medicine; 97(50):e13559. Doi: 10.1097/MD.0000000000013559.
27. Cipresso P., Albani G., Serino S., Pedroli E., (2014) Virtual multiple errands test (VMET): a virtual reality-based tool to detect early executive functions deficit in Parkinson's disease, frontier behaviour neurology, 8:405. Doi: 10.3389/fnbeh.2014.00405.
28. Keller J., Stetkarova I., Macri V., Kuhn S., (2020) Virtual reality-based treatment for regaining upper extremity function induces cortex grey matter changes in persons with acquired brain injury, Journal of Neuroengineering and Rehabilitation volume 17, Article number: 127
29. Norouzi E., Gerber M., Puhseb U., (2020) Combined virtual reality and physical training improved the bimanual coordination of women with multiple sclerosis, Neuropsychological rehabilitation; 31(4):552-569. Doi: 10.1080/09602011.2020.1715231.
30. Aydın A.R., (2020) Virtual Reality Mediated Upper Extremity rehabilitation Patients with Cerebral Palsy, The Scientific and Technological Research Council of Turkey, NCT04529343
31. Beek J., Wegen E., Bohlhalter S., and Vanbellingen T., (2019) Exergaming-Based Dexterity Training in Persons With Parkinson Disease: A Pilot Feasibility Study; Journal of neurologic physical therapy, 43(3):168-174. Doi: 10.1097/NPT.0000000000000278.
32. Carrion P.V.T. , Gonzale C.S.G., Delgado P.A.T., (2019) Improving Cognitive Visual-Motor Abilities in Individuals with Down Syndrome; Sensors (Basel); 19(18): 3984. Doi: 10.3390/s19183984
33. Yin C.W., Sien N.Y., Ying L.A., (2014) Effects of Virtual Reality-Based Rehabilitation on Virtual reality for upper extremity rehabilitation in early stroke: a pilot randomized controlled trial, Clinical rehabilitation ; 28(11):1107-14. Doi: 10.1177/0269215514532851.