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Virtual reality applications for chronic conditions management: A review

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Abstract

Background: Virtual Reality (VR) as a computer technology that simulating real environments and situations exploited in numerous healthcare areas such as chronic diseases. The significance of timely treatment and rehabilitation of patients with chronic conditions is high due to the long lasting nature of these conditions. This paper sought to perform a review of published works in the field of VR application in chronic conditions for treatment and rehabilitation purposes.

Methods: We searched the MEDLINE database through PubMed in April 2016 for retrieving published papers from January 2001 to December 2015. From 117 retrieved papers, 52had the inclusion criteria, and their full texts were accessible. Data were extracted from papers based on following items: the name of the first author, year of the study, applied VR methods, type of condition and disease, number of subjects that participated in the study, and finally the status of success and failure of VR application. Data were analyzed using descriptive analysis.

Results: Results of the reviewed investigations have been considered in two main categories including treatment oriented papers (n=38, 73%) while twenty of these papers have been conducted on phobias (53%); also, there are rehabilitation-oriented experiments (n=14, 27%) while thirteen of these papers have been performed on stroke. In 40 papers (77%), the VR technology application reported proper and in 11 papers (21%) the application of VR resulted in relatively proper outcomes and only there is a work (2%) with poor results for VR intervention.

Conclusion: VR technology has been increasingly used in recent years for treatment and rehabilitation purposes among patients affected by chronic conditions in order to motivate them for more successful management.

Keywords: Virtual reality, Chronic disease, Therapeutic, Rehabilitation

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Introduction

Virtual Reality (VR) is a computer technology stimulating real environments and situations in which the user can interact with the environment in the way that he/she is in the real world. It can create sensory knowledge, such as

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↑What is "already known" in this topic:
Chronic diseases are well known as threats to population health, economic status, and quality of life in communities due to the long-lasting nature of these conditions. Control and management of these conditions are very important. Use of new technologies such as Virtual Reality (VR) may support patients 'improvement in care steps and health providers to manage chronic diseases more easily and successfully. We know the available technology of VR applied for chronic disease management distinctly.

→What this article adds:
This study reviewed applied VR technology for chronic disease more comprehensively; furthermore, this study addressed VR applications based on categories of chronic disease according to their entity and degree of success more specifically for chronic disease treatment and rehabilitation. Result of this study can be useful for the healthcare providers in decision making to choose VR in the management of these conditions.

sight, touch, hearing, and smell (1-3).

VR has several methods such as Window on World Systems (WoW) also called desktop VR that using computer monitor to display 3D environment, Video Mapping that is a type of WoW that show user's body interaction with the world (4), Immersive Systems that often use Head-Mounted Display(HMD) (5), Telepresence that uses a robot to links remote sensors in the real world with the senses of a human operator (6, 7) and Mixed Reality or Augmented Reality uses Telepresence and VR simultaneously together (8).VR technologies can be exploited in various fields such as industry for product design and manufacturing (9), and in the healthcare too (10).VR is used in numerous healthcare areas such as treatment and rehabilitation and in several conditions for example brain injuries (11), psychiatry disorders (12), obesity (13), smoking (14), alcoholism (15). Totally we have named different applications in health care as control which composed of prevention, treatment, and rehabilitation based on the World Health Organization definition (16).

A chronic condition is a disorder that persists for a long time. There are four main categories of chronic conditions, including cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes (17). Other examples of chronic conditions are addiction, chronic pain syndromes, obesity, and psychiatric disorders. The significance of timely treatment and rehabilitation of patients with chronic conditions is high due to the long lasting nature of these conditions. Effectiveness (18, 19), inexpensive (20), improvement (21), able to contribute to the assessment of therapeutic effect (11) have been addressed in different studies related to the proper usages of VR technology. According to the available reports related to VR effectiveness investigation, there are several studies stated phrases such as further study need (22, 23), may enhance (24), used to display relatively proper and did not increase motivation (25) or even phrases notifying VR applications display not proper results.

Use of technologies can help to create greater incentives in patients with chronic conditions for self-management (26). In this study, management refers to the ability of patients for self-management in chronic conditions. Self-management can increase the incentive of patients in the management of their conditions by improving health literacy and behavior of them (26). Several VR technologies such as HMD (Head-Mounted Display), game, hand wrist device, video recording, and other computer applications are used to manage chronic conditions either through enhancing patients' self-management or empowering health care provider to offer certain care to affected patients by specific conditions. Specific reviews have been conducted regarding VR application in special areas of chronic disease, for example, brain injuries (27), psychiatric disorders (2), and also in the education field (28, 29); however, there is no report to review VR application in the management of chronic diseases more comprehensively.

Due to high prevalence and burden of chronic diseases and related risk factors, and great levels of imposed cost especially in low level economic status and consequently their importance in communities' quality of life, control, and management of these conditions is very important (30). It is useful for healthcare providers to understand the applications of VR in management of these conditions as newfound technology for long-lasting treatment and rehabilitation interventions which are essential in care process nowadays (31, 32).

This paper sought to fulfill this research gap through review of papers in the field of VR`s applications for the following aims: to determine chronic conditions management using VR method, type of chronic condition managed by VR technology, the quality of VR usages for studied interventions, types of VR based interventions, and chronological analysis of VR based interventions based on condition type for treatment and rehabilitation purposes.

Methods

This is a review study. We searched the MEDLINE database through PubMed in April 2016 for retrieving published papers from January 2001 to December 2015. We used three separated keywords for searching such as (Virtual Reality Exposure Therapy OR Virtual Reality Immersion Therapy OR Virtual Reality Therapy) AND (Chronic Disease OR Chronic Illness OR Chronically Ill) AND (Medical Informatics Applications), (Virtual Reality Exposure Therapy OR Virtual Reality Immersion Therapy OR Virtual Reality Therapy) AND (Chronic Disease OR Chronic Illness OR Chronically Ill), (Virtual Reality Exposure Therapy) AND "Medical Informatics Applications"[Mesh].

Inclusion criteria were original papers that use VR applications for chronic conditions management. Non-English papers, not available full text, and other types of papers such as conference abstracts, review papers, letters were excluded.

All retrieved records (n=117) imported into Endnote. After removing duplicated records (n=36), remained cases were assessed by two authors independently using titles and abstracts. Disagreements were discussed and resolved by consensus in a joint meeting. Afterward, we removed other 23 records because they were not related to chronic conditions; there were neither research paper nor interventional study. For evaluating final papers, we needed to read the fulltext of papers; unfortunately, we couldn't access full texts of 6 papers (Fig. 1). They were removed too, and the present study has been conducted based on the remained papers. According to the type of this review study, data were gathered from papers based on tabular feature analysis and chronological applications.

The final list of papers was evaluated by two authors independently using full texts. Data were extracted from papers based on six checklist items including the name of the first author, year of the study, applied VR methods, type of condition and disease, number of subjects that participated in the study, and finally the status of success and failure of VR application (Tables 1, 2). Data were analyzed using descriptive analysis.

Results

Of 52 final papers, twenty-six papers reported VR applications for psychiatric disorders such as phobia, schiz-

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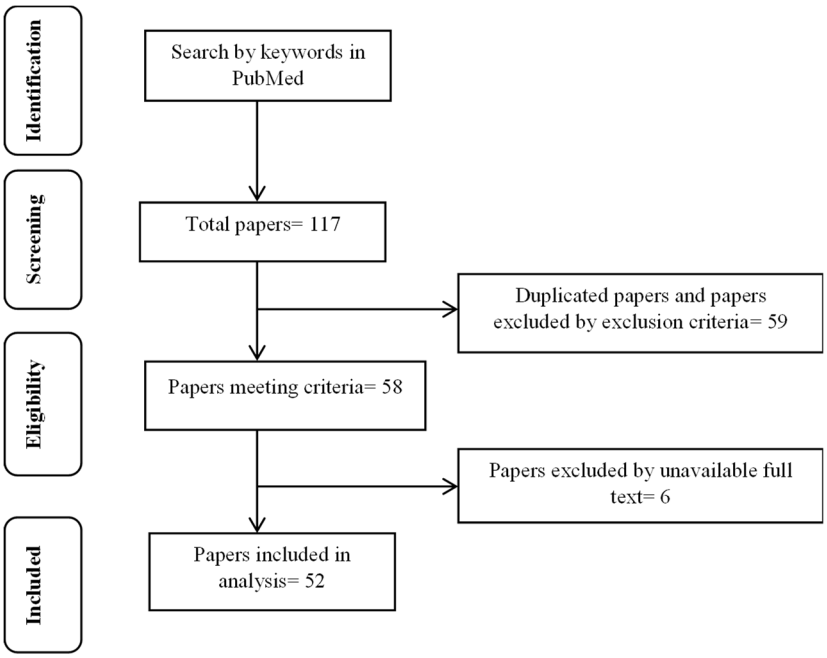

Fig. 1. The process of PRISMA for data collection and analysis

ophrenia and to treat these syndromes by VR, 14 papers on the rehabilitation of injuries due to stroke and Multiple Sclerosis. Other papers have been done on several conditions such as obesity, chronic pains, diabetes, and addiction.

Year oriented papers analysis

During 2001-2005, 13 papers were in the field of treatment; most of them were in the treatment of various phobias (n=11), but no paper was in the field of rehabilitation.

Between 2006 and 2010, 18 papers were in the field of treatment that 6 of them were in the treatment of various phobias, and 4 rehabilitation papers were in the stroke field.

Between 2011 and 2014, 7 papers were in the field of treatment that 2 of them were in the treatment of various phobias, and 10 papers were in the field of rehabilitation that most of them were in the stroke field (n=9).

Treatment-oriented papers analysis

Twenty papers have been done on phobia disorders (flying phobia (n=4), agoraphobia (n=5), acrophobia (n=2), driving phobia (n=1), social phobia (n=1), cockroach phobia (n=2), public speaking phobia (n=2), arachnophobia (n=1)), other papers have been conducted on several conditions such as periodontitis, binge eating disorder, schizophrenia, post-traumatic stress, alcoholism, smoking, pruritus, neck pain, obesity, diabetes, fibromyalgia, cervical

Table 1. Characteristics of reviewed papers in the area of chronic disease treatment

Paper	Year of the study	Applied VR method	Type of Condition	Number of subjects	Status of Application
Banos RM, et al (33)	2001	Head-Mounted Display (HMD)	Flying phobia	Four	P
Hoffman HG, et al (47)	2001	Icy 3-D virtual canyon	Periodontitis	Two	R
Moore K, et al (34)	2001	Head-Mounted Display (HMD)	Panic and Agoraphobia	Nine	R
Alcaniz M, et al (48)	2002	Virtools Dev 3D interactive technology	Panic disorder and agoraphobia	One	R
Jang DP, et al (49)	2002	Realistic virtual environment based on PC	Acrophobia	One	P
Riva G, et al (50)	2002	Head-Mounted Display (HMD)	Binge eating disorder	Twenty	R
Walshe DG, et al (51)	2002	Head Mounted Display(HMD), Game	Driving phobia	Fourteen	P
Wiederhold BK, et al (52)	2002	Liquid Image Head- Mounted Display (HMD)	Flying phobia	Thirty	P
Krijn M, et al (53)	2003	Head-Mounted Display (HMD),computer automatic virtual environment (CAVE)	Acrophobia	Thirty	R
Robillard G, et al (54)	2003	PC computer games	Phobia	Thirteen	P
Roy S, et al (55)	2003	VirtoolsDev 2.0 Education	Social phobia	Not reported	P
Wiederhold BK, et al (56)	2003	Liquid Image Head-Mounted Display (HMD)	Flying phobia	Thirty	P

P=proper, R=relatively proper, N=not proper

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Table 1. Ctd

Botella CM, et al (57)	2004	Head-Mounted Display (HMD)	Cockroach Phobia	One	P
Tichon J, et al(58)	2006	Semi-immersive curved screen to PC	Schizophrenia	Not reported	P
Wood DP, et al (59)	2006	Virtual reality graded exposure therapy (VRGET)	Post-traumatic stress disorder	Not reported	P
Cho S, et al (15)	2007	Head-Mounted Display (HMD)	Alcoholism	Ten	P
Lee JH, et al (60)	2007	Cue-exposure therapy (CET)	Alcoholism	Eight	P
Chan CL, et al (61)	2008	IREX	Schizophrenia	Twenty nine	R
Wallach HS, et al (62)	2008	Head-Mounted Display (HMD)	Public speaking anxiety	One hundred and twelve	P
Clemente M, et al (63)	2009	Functional magnetic resonance imaging (fMRI) machine	phobias to small animals (spiders and cockroaches)	Not reported	P
Leibovici V, et al (64)	2009	Game	Pruritus	Twenty four	R
Perez-AraMA, et al (65)	2009	Virtual Reality Interoceptive Exposure Simultaneous Condition (VRIE-sim)	Panic disorder and agoraphobia	Twenty nine	P
Sarig-Bahat H, et al (66)	2009	Head-Mounted Display (HMD)	Neck pain	Twenty five	P
St-Jacques J, et al (25)	2009	3D game max payne	Arachnophobia	Thirty one	N
Coons MJ, et al (67)	2010	ENGAGED (E-Networks Guiding Adherence to Goals in Exercise and Diet)	Obesity	Not reported	P
Dunser A, et al (68)	2010	Head-Mounted Display (HMD)with an attached USB camera to track AR markers	Phobia	Not reported	P
McLay RN, et al (69)	2010	Virtual reality graded exposure therapy (VRGET)	post-traumatic stress disorder	Ten	P
Meyerbroker K , et al (70)	2010	Computer automatic virtual environment , Head-Mounted Display(HMD)	Agoraphobia	Fourteen	P
Pericot-Valverde I, et al (71)	2010	Cue Exposure Therapy (CET)	Smoking	Fourty six	P
SarigBahat H, et al (72)	2010	Virtual game	Cervical kinematics	Twenty five	P
Tortella-Feliu M, et al (36)	2010	Head-Mounted Display(HMD)	Flying phobia	Sixty	P
Malbos E, et al (35)	2011	Head-Mounted Display (HMD)	Agoraphobia	Ten	P
Poeschl S, et al (73)	2012	Virtual fear-triggering stimuli (exposure)	Fear of Public Speaking	Eighteen	P
Rus-Calafell M, et al (74)	2012	Soskitrain	Schizophrenia	Twelve	P
Difede J, et al (75)	2013	Pharmacotherapy, D -cycloserine (DCS)	Post-Traumatic Stress Disorder	Twenty five	P
Williams GC, et al (76)	2013	Virtual Look AHEAD Program	Type 2 Diabetes	Thirty three	P
Mortensen J, et al (77)	2013	Motion-Controlled Video Games (MCVGs)	Fibromyalgia	Fifteen	P
Thomas JG, et al (78)	2014	3D virtual reality	Obesity	Thirty seven	R

kinematics. In fifteen papers, HMD (Head-Mounted Display) technology was used; in 5 papers games were utilized and in the rest of reports, several technologies such as CET (Cue Exposure Therapy) and VRGET (Virtual Reality Graded Exposure Therapy) were applied (Table 1).

Rehabilitation oriented papers analysis

Thirteen papers have been performed on stroke and one paper on multiple sclerosis. In this field, papers have been used games and real-world video recording as two more used technologies, and hand-wrist assistant rehabilitation device, hand exoskeleton rehabilitation robot, semi-immersive workbench (Table 2).

VR application based on certain condition analysis

For the treatment of flying phobia (n=4 (100%)), agoraphobia (n=3 (60%)), acrophobia (n=1 (50%)), driving phobia (n=1 (100%)), cockroach phobia (n=1 (50%)), public speaking (n=1 (50%)), binge eating disorder (n=1 (100%)), alcoholism (n=1 (100%)) and neck pain (n=1 (100%)) HMD technology has been used. For the treatment of arachnophobia, pruritus, fibromyalgia and cervical kinematics (n=1 (100%)) game technology has been used. For rehabilitation of stroke, hand wrist device (n=4 (31%)), game (n=4 (31%)), application (n=3 (23%)) and video recording (n=2 (15%)) were been used.

VR application success analysis

In 40 out of 52 papers, the result of VR technologies application was proper; in 11 papers, it was relatively proper, and only in 1 paper it was not (Table 3).

VR based interventions analysis

In twenty-three papers, the risk interface intervention in 17 papers, body movement intervention, in 5 papers, concentration improvement intervention and in 7 papers, diet management intervention was used (Table 4). In the risk interface intervention, patients are encountered to the factors that cause fear by using HMD, game, and other applications that set on personal computers. In the body movement intervention, for the rehabilitation of patients that suffer from a disability to move their body part or have pain, use the VR technologies such as game, hand wrist device, HMD and video recording can help to move body parts. In the concentration improvement intervention, the games and other applications are used to reduce pain and increase the sense of the presence of schizo-

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Table 2. Characteristics of reviewed papers in the area of chronic disease rehabilitation

Paper	Year of the study	Applied VR method	Type of Condition	Number of subjects	Status of Application
Broeren J, et al (79)	2006	Semi-immersive workbench	Stroke	Five	R
Stewart JC, et al (80)	2006	Game	Stroke	Two	R
Takahashi CD, et al (81)	2007	Hand Wrist Assistive Rehabilitation Device ('HWARD')	Stroke	Thirteen	P
Godfrey SB, et al (82)	2010	Hand Exoskeleton Rehabilitation Robot (HEXORR)combined with an interactive virtual reality game	Stroke	Four	P
Cameirao MS, et al (41)	2011	Rehabilitation Gaming System	Stroke	Forty four	R
Fluet GG, et al (83)	2011	NJIT-RAVR system and the NJIT Track-Glove system	Stroke	One	P
Subramanian SK, et al (84)	2011	3D virtual reality	Stroke	Thirty two	P
Cho KH, et al (40)	2013	virtual walking training program using a real-world video recording	Stroke	Fourteen	P
Cho KH, et al (39)	2013	Treadmill training based real-world video recording (TBRVR)	Stroke	Thirty	P
Jordan K, et al (42)	2013	Game	Stroke	Thirteen	P
Saleh S, et al (85)	2013	MRI-compatible recording gloves	Stroke	Fifteen	P
Eftekharsadat B, et al (86)	2014	postural stability training program (PST) using the Biodex Balance System SD	Multiple sclerosis	Thirty	P
Llorens R, et al (87)	2014	Virtual rehabilitation system	Stroke	Twenty	P
Yeh SC, et al (11)	2014	Unity3D Game Engine	Stroke	Eight	P

P=proper, R=relatively proper, N=not proper

Table 3. The frequency of the degree of success for various VR technologies applications in different chronic condition support

Conditions	Proper (n(%))	Relatively proper (n(%))	Not proper (n(%))
Flying phobia	4(100)	0	0
Agoraphobia	3(60)	2(40)	0
Acrophobia	1(50)	1(50)	0
Driving phobia	1(100)	0	0
Cockroach phobia	2(100)	0	0
Public speaking phobia	2(100)	0	0
Arachnophobia	0	0	1(100)
Periodontitis	0	1(100)	0
Binge eating disorder	0	1(100)	0
Schizophrenia	2(66.6)	1(33.4)	0
Post-traumatic stress disorder	3(100)	0	0
Alcoholism	2(100)	0	0
General phobia	2(100)	0	0
Social phobia	1(100)	0	0
Smoking	1(100)	0	0
Neck pain	1(100)	0	0
Diabetes	1(100)	0	0
Fibromyalgia	1(100)	0	0
Cervical kinematics	1(100)	0	0
Pruritus	0	1(100)	0
Obesity	1(50)	1(50)	0
Stroke	10(77)	3(23)	0
Multiple sclerosis	1(100)	0	0
Total	40	11	1

phrenia patient. In diet management intervention, HMD and applications are used to help the patients to change their high-risk behavior by showing them the high-risk situation and methods to manage this situation.

Discussion

The aim of this study was to investigate the applications of VR in the management of chronic diseases. Results of this study showed that VR could be used as a technology

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Table 4. VR based interventions for chronic disease patient management according to result of VR application, type of condition, chronological analysis of VR based interventions based on condition type

VR based interventions	Applied VR technology	P	Frequency N(%) R	N	Condition	Chronological analysis of VR based interventions based on condition type Before 2010	2010-2014
Risk interface	HMD, application, game	16(80)	3(15)	1(5)	Phobia	15	5
		3(100)	0	0	Post-traumatic stress disorder	1	2
Body movement	Game, hand wrist device, video recording, application, HMD	10(77)	3(23)	0	stroke	3	10
		1(100)	0	0	Multiple sclerosis	0	1
		1(100)	0	0	Cervical kinematics	0	1
		1(100)	0	0	Neck pain	1	0
		1(100)	0	0	fibromyalgia	0	1
Concentration improvement	Game, application	2(67)	1(33)	0	schizophrenia	2	1
		0	1(100)	0	Periodontitis	1	0
		0	1(100)	0	Pruritus	1	0
Diet management	HMD, application	0	1(100)	0	Binge eating disorder	1	0
		2(100)	0	0	Alcoholism	2	0
		1(50)	1(50)	0	Obesity	0	2
		1(100)	0	0	Type 2 Diabetes	0	1
		1(100)	0	0	Smoking	0	1
Total		40	11	1		27	25

P=proper, R=relatively proper, N=not proper

to treat and rehabilitate chronic diseases. Most of the treatment-oriented papers have been done on phobias. Phobia is one of the mental illnesses in which the person fears from position, place, and object without a logical reason. Sometimes this irrational fear makes trouble for people in their social relations. For the treatment of this disorder, patients should encounter to the factor that causes fear. Nowadays, the use of VR technology can help to the treatment of these patients. Since 2001, HMD technology has been numerously used and continued until 2011, and the most application of this technology has been for the treatment of various types of phobia (33-36). HMD technology using glasses that are placed on the head makes feel of the real world for the patients. This technology makes the patients encounter particular situations that cause fear with the use of these glasses in safe environment, and since the patient knows that the world in front of him is virtual, he can control his fear easily (35). From 2002, computer games mainly were used in order to treat a variety of phobias (20, 25). In phobia diseases, the visual sense has been mostly used with at least one of the sense of touch and hearing.

Most of the rehabilitation oriented papers have been done on stroke. Stroke is a disease caused by disruption of blood supply to a part of brain tissue. Complications of stroke are different depending on which part of the brain's function has been disrupted. Paralysis is one of the most common complications of this condition. Rehabilitation programs began shortly after stroke occurrence through magnetic stimulation of the brain or physiotherapy. Physiotherapists are important part of team who can improve the function of the paralyzed members through training special exercises to the patients (37, 38). Today, with the advancement of technology, use of VR for stroke patient rehabilitation can be very useful in order to improve patient ability to learn how to work out and get used to it; video recording is the most useful tool designed by VR technology to fulfill this requirement (39). Since 2013, video recording has been used to rehabilitate stroke patients (39, 40) .This technology was an innovation providing screenshots that were projected into the screen placed in front of the patient; at the same time, auditory input, which recorded real-sound during real-world video recording, was broadcasting. This technology is used in the field of rehabilitation of stroke through training balance and gait.

The advent of three-dimensional images technology has been caused to more use of VR in the rehabilitation area of stroke patients by producing computer games in recent years. Computer games reached to the peak of use for patients' rehabilitation who affected by stroke until 2014 (11, 41, 42). Computer games can enhance body movement of patients who suffer from stroke by enforcing them to move their bodies to get more points. Stroke patients mostly use touch sense with at least one of the sense of hearing and vision.

In 40 out of 52 papers, the result of VR technologies application was proper; in 11 papers it was relatively proper and only in 1 paper it was not. The results of VR applications for the treatment various types of phobia were proper; however, it was relatively proper, for the rehabilitation of stroke-affected patients. This might be due to this fact that in the process of application of VR for the treatment of phobia, patients encounter frightening factors promptly. This treatment process is simpler requiring less attention and guidances of health care providers in a short period of care. While, this is not the same for rehabilitating stroke affected patients; that is, in order

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to obtain the successful result of VR application for rehabilitation stroke patients, the process of care is much more complex designed in several sessions and a longer period of time with specific supervision of nurses and even physiotherapists strongly required. It seems that preparing all required conditions and factors for rehabilitation stroke patients using VR technology is more formidable rather than phobia treatment purpose by this new technology. Meanwhile, the results of other review papers are in line with this review, too (43, 44).

Before 2010, most of the studies in the field of VR had been done on phobia disorders; however, after 2010, they have been mainly focused on stroke disorder. This might be due to the high prevalence of stroke in recent years, and it became the second cause of death and third cause of disability in the world (45). Therefore, attention to the rehabilitation of stroke patients and returning them to their normal lives become a priority.

The Chronic Care Model (CCM) as a framework to the management of chronic diseases has basic elements to improve health care at community, organization, practice, and patient level (46). This model has 6 elements such as community, the health system, self-management support, delivery system design, decision support, and clinical information systems (46). According to this model`s elements, VR could be used in the management of chronic diseases effectively as it may provide service based on applied guidelines to the patients who do not have access to the healthcare providers, emphasis on the role of patients in managing their conditions. Due to these VR capabilities to improve healthcare, the use of this technology might be increased in routine health care delivery.

According to the results of this study, application of VR in the management of disease other than chronic diseases with similar treatment and rehabilitation intervention are suggested.

Conclusion

VR technology is increasingly in progress to treat and rehabilitate chronic conditions, and it will be used for more conditions gradually; in other words, its application domain is growing wider steadily.

Conflict of Interests

The authors declare that they have no competing interests.

References

1. Levin MF, Weiss PL, Keshner EA. Emergence of virtual reality as a tool for upper limb rehabilitation: incorporation of motor control and motor learning principles. Phys Ther. 2015 Mar;95(3):415-25.
2. Botella C, Serrano B, Banos RM, Garcia-Palacios A. Virtual reality exposure-based therapy for the treatment of post-traumatic stress disorder: a review of its efficacy, the adequacy of the treatment protocol, and its acceptability. Neuropsychiatr Dis Treat. 2015;11:2533-45.
3. Diemer J, Alpers GW, Peperkorn HM, Shiban Y, Muhlberger A. The impact of perception and presence on emotional reactions: a review of research in virtual reality. Front Psychol. 2015;6:26.
4. Villiger M, Estevez N, Hepp-Reymond MC, Kiper D, Kollias SS, Eng K, et al. Enhanced activation of motor execution networks using action observation combined with imagination of lower limb movements. PLoS One. 2013;8(8):e72403.
5. Dargar S, Kennedy R, Lai W, Arikatla V, De S. Towards immersive virtual reality (iVR): a route to surgical expertise. J Comput Surg. 2015 May;2.
6. Pillai JS, Schmidt C, Richir S. Achieving Presence through Evoked Reality. Front Psychol. 2013;4:86.
7. Kondo HM, Pressnitzer D, Toshima I, Kashino M. Effects of self-motion on auditory scene analysis. Proc Natl Acad Sci USA. 2012 Apr 24;109(17):6775-80.
8. Botella C, Perez-Ara MA, Breton-Lopez J, Quero S, Garcia-Palacios A, Banos RM. In Vivo versus Augmented Reality Exposure in the Treatment of Small Animal Phobia: A Randomized Controlled Trial. PLoS One. 2016;11(2):e0148237.
9. Berg LP, Vance JM. Industry use of virtual reality in product design and manufacturing: a survey. Virtual Real. 2016:1-17.
10. Hu J, Luo E, Song E, Xu X, Tan H, Zhao Y, et al. Patients' attitudes towards online dental information and a web-based virtual reality program for clinical dentistry: a pilot investigation in China. Int J Med Inform. 2009 Mar;78(3):208-15.
11. Yeh SC, Lee SH, Chan RC, Chen S, Rizzo A. A virtual reality system integrated with robot-assisted haptics to simulate pinch-grip task: Motor ingredients for the assessment in chronic stroke. NeuroRehabilitation. 2014;35(3):435-49.
12. Maltby N, Kirsch I, Mayers M, Allen GJ. Virtual reality exposure therapy for the treatment of fear of flying: a controlled investigation. J Consult Clin Psychol. 2002 Oct;70(5):1112-8.
13. Cesa GL, Manzoni GM, Bacchetta M, Castelnuovo G, Conti S, Gaggioli A, et al. Virtual reality for enhancing the cognitive behavioral treatment of obesity with binge eating disorder: randomized controlled study with one-year follow-up. J Med Internet Res. 2013 Jun 12;15(6):e113.
14. Pericot-Valverde I, Garcia-Rodriguez O, Ferrer-Garcia M, Secades-Villa R, Gutierrez-Maldonado J. Virtual reality for smoking cessation: a case report. Stud Health Technol Inform. 2012;181:292-6.
15. Cho S, Ku J, Park J, Han K, Lee H, Choi YK, et al. Development and verification of an alcohol craving-induction tool using virtual reality: craving characteristics in social pressure situation. Cyberpsychol Behav. 2008 Jun;11(3):302-9.
16. WHO. Available from: http://www.who.int/trade/glossary/story046/en/.
17. WHO. Noncommunicable diseases [cited April 5, 2016].
18. Baños RM, Botella C, Perpiñá C, Alcañiz M, Lozano JA, Osma J, et al. Virtual reality treatment of flying phobia. IEEE Trans Inf Technol Biomed. 2002;6(3):206-12.
19. Wallach HS, Safir MP, Bar-Zvi M. Virtual reality cognitive behavior therapy for public speaking anxiety: A randomized clinical trial. Behav Modif. 2009;33(3):314-38.
20. Robillard G, Bouchard S, Fournier T, Renaud P. Anxiety and presence during VR immersion: A comparative study of the reactions of phobic and non-phobic participants in therapeutic virtual environments derived from computer games. Cyberpsychol Behav. 2003;6(5):467-76.
21. Difede J, Cukor J, Wyka K, Olden M, Hoffman H, Lee FS, et al. D-cycloserine augmentation of exposure therapy for post-traumatic stress disorder: a pilot randomized clinical trial. Neuropsychopharmacology. 2014;39(5):1052-8.
22. Riva G, Bacchetta M, Baruffi M, Molinari E. Virtual-reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: a preliminary controlled study. IEEE Trans Inf Technol Biomed. 2002;6(3):224-34.
23. Chan CL, Ngai EK, Leung PK, Wong S. Effect of the adapted virtual reality cognitive training program among Chinese older adults with chronic schizophrenia: a pilot study. Int J Geriatr Psychiatry. 2010;25(6):643-9.
24. Broeren J, Rydmark M, Björkdahl A, Sunnerhagen KS. Assessment and training in a 3-dimensional virtual environment with haptics: a report on 5 cases of motor rehabilitation in the chronic stage after stroke. Neurorehabil Neural Repair. 2007;21(2):180-9.
25. St-Jacques J, Bouchard S, Belanger C. Is virtual reality effective to motivate and raise interest in phobic children toward therapy? A clinical trial study of in vivo with in virtuo versus in vivo only treatment exposure. J Clin Psychiatry. 2010 Jul;71(7):924-31.
26. Ownby RL, Acevedo A, Waldrop-Valverde D, Caballero J, Simonson M, Davenport R, et al. A Mobile App for Chronic Disease

[DOI: 10.47176/mjiri.33.67]

Self-Management: Protocol for a Randomized Controlled Trial. JMIR Res Protoc. 2017 Apr 05;6(4):e53.
27. Shin H, Kim K. Virtual reality for cognitive rehabilitation after brain injury: a systematic review. J Phys Ther Sci. 2015 Sep;27(9):2999-3002.
28. Jenson CE, Forsyth DM. Virtual reality simulation: using three-dimensional technology to teach nursing students. Comput Inform Nurs. 2012;30(6):312-8.
29. Vaughn J, Lister M, Shaw RJ. Piloting Augmented Reality Technology to Enhance Realism in Clinical Simulation. Comput Inform Nurs. 2016;34(9):402-5.
30. Feigin VL, Roth GA, Naghavi M, Parmar P, Krishnamurthi R, Chugh S, et al. Global burden of stroke and risk factors in 188 countries, during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet Neurol. 2016;15(9):913-24.
31. Rose T, Nam CS, Chen KB. Immersion of virtual reality for rehabilitation-Review. Applied ergonomics. 2018;69:153-61.
32. Norr AM, Smolenski DJ, Katz AC, Rizzo AA, Rothbaum BO, Difede J, et al. Virtual reality exposure versus prolonged exposure for PTSD: Which treatment for whom? Depress Anxiety. 2018;35(6):523-9.
33. Banos RM, Botella C, Perpina C, Alcaniz M, Lozano JA, Osma J, et al. Virtual reality treatment of flying phobia. IEEE Trans Inf Technol Biomed. 2002 Sep;6(3):206-12.
34. Moore K, Wiederhold BK, Wiederhold MD, Riva G. Panic and agoraphobia in a virtual world. Cyberpsychol Behav. 2002 Jun;5(3):197-202.
35. Malbos E, Rapee RM, Kavakli M. Isolating the effect of Virtual Reality Based Exposure Therapy for agoraphobia: a comparative trial. Stud Health Technol Inform. 2011;167:45-50.
36. Tortella-Feliu M, Botella C, Llabres J, Breton-Lopez JM, del Amo AR, Banos RM, et al. Virtual reality versus computer-aided exposure treatments for fear of flying. Behav Modif. 2011 Jan;35(1):3-30.
37. Hernandez-Cardenache R, Johnson-Greene D. Rehabilitation in Stroke. Neuropsychol Rehabil. 2013:161.
38. Askim T, Indredavik B, Engen A, Roos K, Aas T, Mørkved S. Physiotherapy after stroke: To what extent is task-oriented practice a part of conventional treatment after hospital discharge? Physiother Theory Pract. 2013;29(5):343-50.
39. Cho KH, Lee WH. Effect of treadmill training based real-world video recording on balance and gait in chronic stroke patients: a randomized controlled trial. Gait Posture. 2014;39(1):523-8.
40. Cho KH, Lee WH. Virtual walking training program using a real-world video recording for patients with chronic stroke: a pilot study. Am J Phys Med Rehabil. 2013 May;92(5):371-80; quiz 80-2, 458.
41. Cameirao MS, Badia SB, Duarte E, Frisoli A, Verschure PF. The combined impact of virtual reality neurorehabilitation and its interfaces on upper extremity functional recovery in patients with chronic stroke. Stroke. 2012 Oct;43(10):2720-8.
42. Jordan K, Sampson M, King M. Gravity-supported exercise with computer gaming improves arm function in chronic stroke. Arch Phys Med Rehabil. 2014 Aug;95(8):1484-9.
43. Massetti T, Trevizan IL, Arab C, Favero FM, Ribeiro-Papa DC, de Mello Monteiro CB. Virtual reality in multiple sclerosis - A systematic review. Mult Scler Relat Disord. 2016 Jul;8:107-12.
44. Luque-Moreno C, Ferragut-Garcias A, Rodriguez-Blanco C, Heredia-Rizo AM, Oliva-Pascual-Vaca J, Kiper P, et al. A Decade of Progress Using Virtual Reality for Poststroke Lower Extremity Rehabilitation: Systematic Review of the Intervention Methods. Biomed Res. Int 2015;2015:342529.
45. WHO. The top 10 causes of death 2018 [cited 2018 August]. Available from: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death.
46. Innovation MCfHC. The Chronic Care Model 2011 [cited 2018 December]. Available from: http://www.improvingchroniccare.org/index.php?p=The_Chronic_Care_Model&s=2.
47. Hoffman HG, Garcia-Palacios A, Patterson DR, Jensen M, Furness T, 3rd, Ammons WF, Jr. The effectiveness of virtual reality for dental pain control: a case study. Cyberpsychol Behav 2001 Aug;4(4):527-35.
48. Alcaniz M, Botella C, Banos R, Perpina C, Rey B, Lozano JA, et al. Internet-based telehealth system for the treatment of agoraphobia. Cyberpsychol Behav. 2003 Aug;6(4):355-8.
49. Jang DP, Ku JH, Choi YH, Wiederhold BK, Nam SW, Kim IY, et al. The development of virtual reality therapy (VRT) system for the treatment of acrophobia and therapeutic case. IEEE Trans Inf Technol Biomed 2002 Sep;6(3):213-7.
50. Riva G, Bacchetta M, Baruffi M, Molinari E. Virtual-reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: a preliminary controlled study. IEEE Trans Inf Technol Biomed 2002 Sep;6(3):224-34.
51. Walshe DG, Lewis EJ, Kim SI, O'Sullivan K, Wiederhold BK. Exploring the use of computer games and virtual reality in exposure therapy for fear of driving following a motor vehicle accident. Cyberpsychol Behav 2003 Jun;6(3):329-34.
52. Wiederhold BK, Jang DP, Gevirtz RG, Kim SI, Kim IY, Wiederhold MD. The treatment of fear of flying: a controlled study of imaginal and virtual reality graded exposure therapy. IEEE Trans Inf Technol Biomed 2002 Sep;6(3):218-23.
53. Krijn M, Emmelkamp PM, Biemond R, de Wilde de Ligny C, Schuemie MJ, van der Mast CA. Treatment of acrophobia in virtual reality: the role of immersion and presence. Behav Res Ther 2004 Feb;42(2):229-39.
54. Robillard G, Bouchard S, Fournier T, Renaud P. Anxiety and presence during VR immersion: a comparative study of the reactions of phobic and non-phobic participants in therapeutic virtual environments derived from computer games. Cyberpsychol Behav 2003 Oct;6(5):467-76.
55. Roy S, Klinger E, Legeron P, Lauer F, Chemin I, Nugues P. Definition of a VR-based protocol to treat social phobia. Cyberpsychol Behav 2003 Aug;6(4):411-20.
56. Wiederhold BK, Wiederhold MD. Three-year follow-up for virtual reality exposure for fear of flying. Cyberpsychol Behav 2003 Aug;6(4):441-5.
57. Botella CM, Juan MC, Banos RM, Alcaniz M, Guillen V, Rey B. Mixing realities? An application of augmented reality for the treatment of cockroach phobia. Cyberpsychol Behav 2005 Apr;8(2):162-71.
58. Tichon J, Banks J. Virtual reality exposure therapy: 150-degree screen to desktop PC. Cyberpsychol Behav 2006 Aug;9(4):480-9.
59. Wood DP, Murphy J, Center K, McLay R, Reeves D, Pyne J, et al. Combat-related post-traumatic stress disorder: a case report using virtual reality exposure therapy with physiological monitoring. Cyberpsychol Behav 2007 Apr;10(2):309-15.
60. Lee JH, Kwon H, Choi J, Yang BH. Cue-exposure therapy to decrease alcohol craving in virtual environment. Cyberpsychol Behav 2007 Oct;10(5):617-23.
61. Chan CL, Ngai EK, Leung PK, Wong S. Effect of the adapted Virtual Reality cognitive training program among Chinese older adults with chronic schizophrenia: a pilot study. Int J Geriatr Psychiatry 2010 Jun;25(6):643-9.
62. Wallach HS, Safir MP, Bar-Zvi M. Virtual reality cognitive behavior therapy for public speaking anxiety: a randomized clinical trial. Behav Modif 2009 May;33(3):314-38.
63. Clemente M, Rey B, Alcaniz M, Breton-Lopez J, Moragrega I, Banos RM, et al. Contributions of functional magnetic resonance in the field of psychological treatments with virtual reality. Stud Health Technol Inform 2010;154:197-201.
64. Leibovici V, Magora F, Cohen S, Ingber A. Effects of virtual reality immersion and audiovisual distraction techniques for patients with pruritus. Pain Res Manag 2009 Jul-Aug;14(4):283-6.
65. Perez-Ara MA, Quero S, Botella C, Banos R, Andreu-Mateu S, Garcia-Palacios A, et al. Virtual reality interoceptive exposure for the treatment of panic disorder and agoraphobia. Stud Health Technol Inform 2010;154:77-81.
66. Sarig-Bahat H, Weiss PL, Laufer Y. Neck pain assessment in a virtual environment. Spine 2010 Feb 15;35(4):E105-12.
67. Coons MJ, Roehrig M, Spring B. The potential of virtual reality technologies to improve adherence to weight loss behaviors. J Diabetes Sci Technol 2011 Mar;5(2):340-4.
68. Dunser A, Grasset R, Farrant H. Towards immersive and adaptive augmented reality exposure treatment. Stud Health Technol Inform 2011;167:37-41.
69. McLay RN, Wood DP, Webb-Murphy JA, Spira JL, Wiederhold MD, Pyne JM, et al. A randomized, controlled trial of virtual reality-graded exposure therapy for post-traumatic stress disorder in active duty service members with combat-related post-traumatic stress disorder. Cyberpsychol Behav Soc Netw 2011 Apr;14(4):223-9.
70. Meyerbroker K, Morina N, Kerkhof G, Emmelkamp PM. Virtual reality exposure treatment of agoraphobia: a comparison of computer

[DOI: 10.47176/mjiri.33.67]

automatic virtual environment and head-mounted display. Stud Health Technol Inform. 2011;167:51-6.
71. Pericot-Valverde I, Garcia-Rodriguez O, Gutierrez-Maldonado J, Ferrer-Garcia M, Secades-Villa R. Evolution of smoking urge during exposure through virtual reality. Stud Health Technol Inform. 2011;167:74-9.
72. Sarig Bahat H, Weiss PL, Laufer Y. The effect of neck pain on cervical kinematics, as assessed in a virtual environment. Arch Phys Med Rehabil. 2010 Dec;91(12):1884-90.
73. Poeschl S, Doering N. Designing virtual audiences for fear of public speaking training - an observation study on realistic nonverbal behavior. Stud Health Technol Inform. 2012;181:218-22.
74. Rus-Calafell M, Gutierrez-Maldonado J, Ribas-Sabate J. Neurocognition, presence and acceptance of a VR programme for psychotic patients: a correlational study. Stud Health Technol Inform. 2013;191:141-5.
75. Difede J, Cukor J, Wyka K, Olden M, Hoffman H, Lee FS, et al. D-cycloserine augmentation of exposure therapy for post-traumatic stress disorder: a pilot randomized clinical trial. Neuropsychopharmacology. 2014 Apr;39(5):1052-8.
76. Williams GC, Niemiec CP, Elliot AJ, LaGuardia JG, Gorin AA, Rigby CS. Virtual Look AHEAD program: initial support for a partly virtualized intensive lifestyle intervention in type 2 diabetes. Diabetes Care. 2014 Aug;37(8):e169-70.
77. Mortensen J, Kristensen LQ, Brooks EP, Brooks AL. Women with fibromyalgia's experience with three motion-controlled video game consoles and indicators of symptom severity and performance of activities of daily living. Disabil Rehabil Assist Technol. 2015 Jan;10(1):61-6.
78. Thomas JG, Spitalnick JS, Hadley W, Bond DS, Wing RR. Development of and feedback on a fully automated virtual reality system for online training in weight management skills. J Diabetes Sci Technol. 2015 Jan;9(1):145-8.
79. Broeren J, Rydmark M, Bjorkdahl A, Sunnerhagen KS. Assessment and training in a 3-dimensional virtual environment with haptics: a report on 5 cases of motor rehabilitation in the chronic stage after stroke. Neurorehabil Neural Repair. 2007 Mar-Apr;21(2):180-9.
80. Stewart JC, Yeh SC, Jung Y, Yoon H, Whitford M, Chen SY, et al. Intervention to enhance skilled arm and hand movements after stroke: A feasibility study using a new virtual reality system. J Neuroeng Rehabil. 2007;4:21.
81. Takahashi CD, Der-Yeghiaian L, Le V, Motiwala RR, Cramer SC. Robot-based hand motor therapy after stroke. Brain. 2008 Feb;131(Pt 2):425-37.
82. Godfrey SB, Schabowsky CN, Holley RJ, Lum PS. Hand function recovery in chronic stroke with HEXORR robotic training: A case series. Conf Proc IEEE Eng Med Biol Soc. 2010;2010:4485-8.
83. Fluet GG, Merians AS, Qiu Q, Lafond I, Saleh S, Ruano V, et al. Robots integrated with virtual reality simulations for customized motor training in a person with upper extremity hemiparesis: a case study. J Neurol Phys Ther. 2012 Jun;36(2):79-86.
84. Subramanian SK, Lourenco CB, Chilingaryan G, Sveistrup H, Levin MF. Arm motor recovery using a virtual reality intervention in chronic stroke: randomized control trial. Neurorehabil Neural Repair. 2013 Jan;27(1):13-23.
85. Saleh S, Adamovich SV, Tunik E. Mirrored feedback in chronic stroke: recruitment and effective connectivity of ipsilesional sensorimotor networks. Neurorehabil Neural Repair. 2014 May;28(4):344-54.
86. Eftekharsadat B, Babaei-Ghazani A, Mohammadzadeh M, Talebi M, Eslamian F, Azari E. Effect of virtual reality-based balance training in multiple sclerosis. Neurol Res. 2015 Jun;37(6):539-44.
87. Llorens R, Gil-Gomez JA, Alcaniz M, Colomer C, Noe E. Improvement in balance using a virtual reality-based stepping exercise: a randomized controlled trial involving individuals with chronic stroke. Clin Rehabil. 2015 Mar;29(3):261-8.

[DOI: 10.47176/mjiri.33.67]