Progress in IS

Yesha Sivan *Editor*

Handbook on 3D3C Platforms

Applications and Tools for Three Dimensional Systems for Community, Creation and Commerce

This book presents 3D3C platforms – three-dimensional systems for community, creation and commerce. It discusses tools including bots in social networks, team creativity, privacy, and virtual currencies & micropayments as well as their applications in areas like healthcare, energy, collaboration, and art. More than 20 authors from 10 countries share their experiences, research findings and perspectives, offering a comprehensive resource on the emerging field of 3D3C worlds. The book is designed for both the novice and the expert as a way to unleash the emerging opportunities in 3D3C worlds.

This Handbook maps with breadth and insight the exciting frontier of building virtual worlds with digital technologies.
David Perkins, Research Professor, Harvard Graduate School of Education

This book is from one of the most adventurous and energetic persons I have ever met. Yesha takes us into new undiscovered spaces and provides insight into phenomena of social interaction and immersive experiences that transform our lives.
Cees de Bont, Dean of School of Design & Chair Professor of Design, School of Design of the Hong Kong Polytechnic University

When you read 3D3C Platforms you realize what a domain like ours -- 3D printing -- can and should do for the world. Clearly we are just starting. Inspiring.
David Reis, CEO, Stratasys Ltd

This book provides a stunning overview regarding how virtual worlds are reshaping possibilities for identity and community. The range of topics addressed by the authors—from privacy and taxation to fashion and health care—provide a powerful roadmap for addressing the emerging potential of these online environments.
Tom Boellstorff, Professor, Department of Anthropology, University of California, Irvine

Handbook on 3D3C Platforms amassed a unique collection of multidisciplinary academic thinking. A primer on innovations that will touch every aspect of the human community in the 21st century.
Eli Talmor, Professor, London Business School

Management / Business for Professionals

ISSN 2196-8705

ISBN 978-3-319-22040-6

9 783319 220406

springer.com

Sivan *Ed.*

Handbook on 3D3C Platforms

Progress in IS

Yesha Sivan *Editor*

Handbook on 3D3C Platforms

Applications and Tools for Three Dimensional Systems for Community, Creation and Commerce

Springer

Editor
Yesha Sivan
Faculty of Management
Tel Aviv University
Tel Aviv, Israel

ISSN 2196-8705 ISSN 2196-8713 (electronic)
Progress in IS
ISBN 978-3-319-22040-6 ISBN 978-3-319-22041-3 (eBook)
DOI 10.1007/978-3-319-22041-3

Library of Congress Control Number: 2015953453

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

To my mentors:
Judah Schwartz, David Perkins, and Israel Zang

Acknowledgments

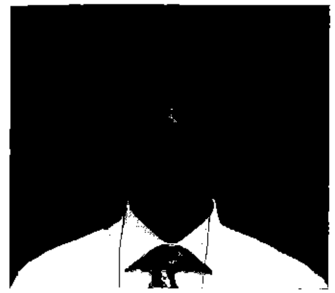
I would like to thank our community of researchers and authors who conducted their research and shared the results in this book. Further, to Mrs. Anshe Chung for her inspiration, to Ms. Tzafnat Shpak for managing and coordinating, and to Mr. Christian Rauscher our publisher from Springer.

I dedicate this book to the three mentors who have guided me in various phases of my life, Prof. Judah Schwartz, Prof. David Perkins, and Prof. Israel Zang. In many ways, this book is your grandchild.

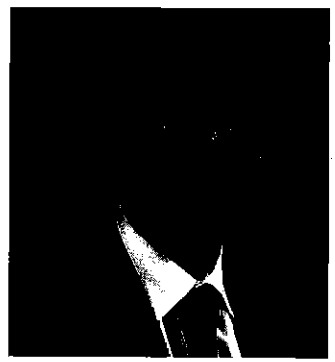
Tel Aviv, Israel Yesha Sivan

Contents

About the Authors



Yesha Sivan is the Executive Director of The Coller Institute of Venture at Tel Aviv University's Faculty of Management and the Director of the Executive Master of Meaningful Innovation (EMMI) at the Hong Kong Polytechnic University (PolyU), Design School. He is also the founder of Metaverse Labs (MVL)—a leading think tank focusing on innovation via virtual and real worlds. Sivan's professional experience includes developing and deploying innovative solutions for corporate, hi-tech, government, and defense environments (see, for example, the Harvard 9-Keys for Knowledge Infrastructure). He published numerous papers in the areas of strategy and IT, innovation and venture, knowledge, 3D3C virtual worlds, and standards. Sivan received his doctorate from Harvard University. He has taught EMBA, MBA, engineering, and design courses in his areas of expertise. His blog is http://www.dryesha.com.



Ibrahim Abosag is an associate professor in marketing at the University of London, SOAS. Ibrahim has published in various academic and professional journals including *Industrial Marketing Management, International Business Review, European Journal of Marketing, Journal of Marketing Management*, and others.

Forte, M., & Siliotti, A. (1997). *Virtual archaeology: Re-creating ancient worlds*. New York, NY: H.N. Abrams.
Foucault, M. (1969). *L'Archéologie du Savoir*. Paris: Gallimard. English edition: Foucault, M. (2002). *The archaeology of knowledge* (A. M. Sheridan Smith, Trans.). London: Routledge.
Frisher, B., Niccolucci, F., Ryan, N. S., & Barceló, J. A. (2002). From CVR to CVRO: The past, present and future of cultural virtual reality. In *Proceedings of VAST 2000* (pp. 7–18).
Hodder, I. (1997). 'Always Momentary, Fluid and Flexible': Towards a reflexive excavation methodology. *Antiquity, 71*, 691–700.
Hodder, I. (2000). *Towards reflexive method in archaeology: The example at Çatalhöyük*. Cambridge: University of Cambridge, distributed by Oxbow Books.
Lercari, N. (2010a). An open source approach to cultural heritage: Nu.M.E. project and the virtual reconstruction of Bologna. In M. Forte (Ed.), *Cyber-archaeology* (pp. 125–133). Oxford: Archeo press.
Lercari, N. (2010b). Nuove Forme di Comunicazione per Nu.M.E. In F. Bocchi & R. Smurra (Eds.), *La Storia della Città per il Museo Virtuale di Bologna* (pp. 217–225). Bologna: Bononia University Press.
Lercari, N., Toffalori, E., Spigarolo, M., & Onsurez, L. (2011). Virtual heritage in the cloud: New perspectives for the virtual museum of bologna. In *Proceedings of VAST 2011: The International Symposium on Virtual Reality, Archaeology And Intelligent Cultural Heritage* (pp. 153–160).
Merlot-Ponty, M. (1945). *La phénoménologie de la perception*. Paris: Gallimard. English edition: Merlot-Ponty, M. (2012). *The phenomenology of perception* (D. A. Landes, Trans.). London: Routledge.
Morgan, C. (2009). (Re)Building Çatalhöyük: Changing virtual reality in archaeology. *Journal of the World Archaeological Congress, 5*(3), 468–487. doi:10.1007/s11759-009-9113-0.
Sequiera, L. M., & Morgado, L. (2013). Virtual archaeology in Second Life and OpenSimulator. *Journal of Virtual Worlds Research, 6*(1), 1–16. doi:10.4101/jvwr.v6i1.704.
Sivan, Y. (2008). 3D3C Real Virtual Worlds Defined: The immense potential of merging 3D, community, creation, and commerce. *Journal of Virtual Worlds Research*, 1(1) (Special issue: Virtual worlds research: Past, present & future). ISSN 1941-8477.
Varela, F., Thompson, E., & Rosh, E. (1993). *The embodied mind. Cognitive science and human experience* (pp. 172–184). Cambridge, MA: The MIT Press.
Woodward, J. F. (1991). Reconstructing history with computer graphics. *Computer Graphics, 11* (1), 2–3.

Virtual Reality in Medicine

Claudio Pensieri and Maddalena Pennacchini

1 Introduction

In recent years, new technologies, like robotics, laparoscopic instruments, 3D, virtual reality, virtual environments etc., generated both excitement and confusion in medicine. The first healthcare applications of VR started in the early '90s with to the need of medical staff to visualize complex medical data, particularly during surgery and for surgery planning (Chinnock, 1994). These factors are evident in the extensive material published in both scientific and popular press, and in the possibly unrealistic expectations held by healthcare professionals (Riva & Wiederhold, 2002).

The growing interest in medical applications of VR is also highlighted by the increasing number of scientific articles published every year on this topic: in 2003 Riva found 951 papers on MEDLINE and 708 on Psycinfo with the search term "Virtual Reality" (Riva, 2003).

In 2006, searching Medline with the keyword "virtual reality", the total number of publications increased from 45 in 1995 to 951 in 2003 (Gorini & Riva, 2005) and to 3203 in 2010 (Riva, Gaggioli, Grassi et al., 2011).

There are currently a large number of articles about medically related VR. In February 2012, the authors found 3443 articles about "Virtual Reality" on Pubmed. The aim was to make an overview of the reviews (meta-Review), in order to limit the research to four areas (1. Communication Interface; 2. Medical Education; 3. Surgical Simulation; and 4. Therapy), given the large number of publications.

C. Pensieri (✉) • M. Pennacchini
Institute of Philosophy of Scientific and Technological Activity, Campus Bio-Medico University of Rome, Rome, Italy
e-mail: c.pensieri@unicampus.it

Y. Sivan (ed.), *Handbook on 3D3C Platforms*, Progress in IS,
DOI 10.1007/978-3-319-22041-3_14

2 Methods

2.1 *Keyterms Search on Pubmed and Psycinfo*

Reviewers searched (Table 1) for the term "Virtual Reality" on Pubmed, Psycinfo, JMIR (Journal of Medical Internet Research) and Isiknowledge and noted that in 2010 a search for VR in Pubmed resulted in 2960 articles, which increased to 3290 in 2011, (+330 articles) and 3443 in February 2012. On Psycinfo the number of articles found using the same term increased from 29 in 2010 to 114 in 2011 (+85 articles) and on Isiknowledge from 6213 to 8237 (+2024 articles).

However, VR was not the only term searched. Additional terms used on PUBMED included the words: "Metaverse" (2 articles), "Second Life" (69 in 2010, 103 in 2011), "Virtual World" (151 in 2010, 200 in 2011) and "Virtual Life" (7 in 2010, 10 in 2011). These words are not completely representative of the entire world of VR applications in healthcare, but they are the most used. We could also add: Virtual Environment, Augmented Reality, Multiverse, etc. It is also important, and a criticality of this study, that the four search engines taken into consideration are not enough to make this review completely exhaustive, as APA search engine and others have not been employed.

2.2 *Four Areas Reviews*

According to Riva's definition on *"Application of Virtual Environment in Medicine"* (Riva, 2003), the authors divided the findings into four main areas:

1. Communication Interface: Presence and Avatar.
2. Medical Educational: training.
3. Surgical Simulation: (a) Neurosurgery, (b) Laparoscopic & Endoscopic, (c) Simulators, (d) Other.
4. Therapy: (a) Phobias, PTSD, Anxiety Disorders, (b) Rehabilitation, (c) Clinical and Pain Management.

Table 1 Keyterms researched

	29/03/10	23/03/11	**28/09/11**	29/03/10	23/03/11	**28/09/11**	**28/09/11**	**20/02/12**	29/03/10	**23/03/11**
	Pub Med			**Psycinfo**			**JMIR**		**Isiknowledge**	
"Virtual Reality"	2960	3126	**3290**	29	35	**114**	4	**4**	6213	**237**
"Metaverse"	2	2	**2**	0	0	**0**	0	**0**	16	**21**
"Second Life"	69	92	**103**	1	1	**18**	54	**62**	256	**375**
"Virtual World"	151	191	**200**	2	2	**33**	4	**5**	711	**901**
"Virtual Life"	7	8	**10**	1	1	**1**	0	**0**	37	**45**

The authors also completed a review of reviews (meta-review), and searched for articles including the words "Virtual Reality" or "Virtual Environment" in the titles or in the abstracts on Pubmed. The search for "Virtual Reality" (Title/Abstract) gave 364 results (03/10/2011). Only 197 had to do with VR, with the Augmented Reality or the Virtual Environment (VE).

3 Results

3.1 *VR as a Communication Interface: Presence and Avatar*

VR provide the remote patient with a feeling of embodiment that has the potential to facilitate the clinical communication process and positively influence group cohesiveness in group-based therapies (Gorini, Gaggioli, & Riva, 2007).

Further studies on VR analyzed multiple simultaneous users, in particular the patient and the therapist, who can communicate with each other through their avatars. VR have been used to examine and investigate the ability of recognizing emotions (Moore, Cheng, McGrath, & Powell, 2005) and also to improve social interaction, teaching students how to express their emotions and understand those of other people (Cheng & Ye, 2010). All these studies yielded encouraging results in identifying emotions and in the improvement of social performance after the intervention (Fig. 1).

More than the richness of available images, the effectiveness of a virtual environment (VE) depends on the level of interaction/interactivity which actors have in both "real" and simulated environments. According to Sastry and Boyd (1998), a VR, particularly when it is used for real world applications, is effective when "the user is able to navigate, select, pick, move and manipulate an object much more naturally". In this sense, emphasis shifts from the quality of the image to

Fig. 1 Advanced army medical technology initiative—amputee virtual environment support space

the freedom of the interaction, from the graphic perfection of the system to the affordances provided to the users in the environment (Satava & Ellis, 1994). Furthermore, as the underlying enabling technologies continue to evolve and allow us to design more useful and usable structural virtual environments, the next important challenge will involve populating these environments with virtual representations of humans (avatars) (Rizzo, Neumann, Enciso, Fidaleo, & Noh, 2001).

The key characteristic of VR, differentiating it from other media or communication systems, is the sense of *presence* (Ijsselsteijn, Lombard, & Freeman, 2001; Riva, Davide, & Ijsselsteijn, 2003).

"*Presence*" is defined as the "*sense of being there*", or as the "*feeling of being in a world that exists outside of the self*" (Riva, Waterworth, & Waterworth, 2004). It is now widely acknowledged that presence can be considered as a neuropsychological phenomenon (Riva, Anguera, Wiederhold, & Mantovani, 2006). Different studies indicate a direct connection between the intensity of the emotions experienced in VR and the level of presence by which it is elicited (Riva, Mantovani, Capideville et al., 2007).

In particular, Riva et al. (2004) describe presence as a defining feature of the self, related to the evolution of a key feature of any central nervous system: the embedding of sensory-referred properties into an internal functional space.

VR and Avatar:

The inhabitants of virtual environments can be classified as *bots* and *avatars*. A *bot* is an autonomous agent that pursues its own goals. On the contrary, an *avatar*—a representation of a human being—is under the direct control of that human being (Whalen, Petriu, Yang, Petriu, & Cordea, 2003). A typical humanoid avatar like those defined by the H-Anim Standard (ISO/IEC FCD 19774) contains more than four dozen joints (not including the additional joints in the spine which have limited mobility).

This example proves that the avatar's behaviour needs only represents human behaviour to a certain extent. It is impossible in practice for any representation to be exact—perfect faithfulness is impossible—but at any level of fidelity, a closer approximation could always be obtained. There are no absolute criteria—one must choose the level of faithfulness which is most cost-effective to meet the needs imposed by each application. People and their avatars have two classes of behaviours: *independent* and *interactive* (Yang, Petriu, Whalen et al., 2003).

Independent behaviours, such as waving a hand, are performed by the avatar alone; they can depend on other objects in the environment.

Interactive behaviours, like picking up a pen or shaking hands, require that the avatar locates other objects, possibly objects moving unpredictably in the environment, and moves in relation to those objects.

Fig. 2 University of Plymouth Sexual Health SIM in Second Life

Another VR application used as a communication interface for physicians may be the 4D GIS (four-dimensional Geographic Information Systems comprising three-dimensional 3D GIS, plus the temporal/real-time dimension) which serves very well the classic public health Person-Place-Time Triad.

Kamel Boulos (2009) proposed to develop a 4D GIS collaborative and interactive platform which combines virtual globes or 3D mirror worlds and 3D virtual worlds and complements, and tightly integrates them with other key technologies, e.g., real-time, geo-tagged RSS-Really Simple Syndication feeds and geo-mash-ups. Such a platform would be much suited for emergency and disaster management in real-time, e.g., for managing an influenza pandemic and coordinating actions at global, regional and local levels. Another one is the Interactive 3D Earth globe for accessing web-based, geographically-indexed information (Kamel Boulos & Burden, 2007). This globe in Second Life offered access to web-based statistics and information about sexually transmitted infections (STIs)/HIV/AIDS from 53 European region countries. The globe is part of the University of Plymouth Sexual Health SIM in Second Life (Kamel Boulos, Hetherington, & Wheeler, 2007) (Fig. 2).

Starting from literature that documented the extent to which people are using the Internet to enquire about their real life health (Madden & Fox, 2006), in 2008 Gonzalez (2009) started a research in SL, expecting to observe a similar interest in personal health in Second Life. Yet while she visited numerous medical sites and clinics in SL, she found them all empty. Universities, clinics and other health organizations had made a considerable effort to set up elaborate architectural structures with placards and displays of health information, but not a single avatar was in sight. Gonzalez wandered these empty structures, looking for health-seeking behavior in SL, but in vain. The only clinic where she found avatars was a setting for sexual role play in which people enacted sexual fantasies between doctors and patients (Table 2).

Table 2 Communication interface

	Communication interface		
Wann JP, Rushton S, Mon-Williams M.	Natural problems for stereoscopic depth perception in Virtual Environments.	Vision Res. Oct;35 (19):2731–6.	1995
Steffin M.	Virtual reality therapy of multiple sclerosis and spinal cord injury: design consideration for a haptic-visual interface.	Stud Health Technol Inform.;44:185–208.	1997
Rushton SK, Riddell PM.	Developing visual systems and exposure to virtual reality and stereo displays: some concerns and speculations about the demands on accommodation and vergence	Appl Ergon. Feb;30 (1):69–78.	1999
Wilson JR.	Virtual environments applications and applied ergonomics	Appl Ergon. Feb;30 (1):3–9.	1999
Haase J.	Neuronavigation	Childs Nerv Syst. Nov;15(11–12): 755–7.	1999
Marsh A.	The integration of virtual reality into a Web-based telemedical information society	Stud Health Technol Inform.;79: 305–25.	2000
Anderson PL, Rothbaum BO, Hodges L.	Virtual reality: using the virtual world to improve quality of life in the real world.	Bull Menninger Clin. Winter;65(1):78–91.	2001
Evett L, Tan YK.	Talk your way round--a speech interface to a virtual museum	Disabil Rehabil. Jul 20-Aug 15;24 (11–12):607–12. Review.	2002
Sanchez-Vives MV, Slater M.	From presence to consciousness through virtual reality	Nat Rev Neurosci. Apr;6(4):332–9.	2005
Erren-Wolters CV, van Dijk H, de Kort AC, Ijzerman MJ, Jannink MJ.	Virtual reality for mobility devices: training applications and clinical results: a review	Int J Rehabil Res. Jun;30(2):91–6.	2007
Davis RL.	Exploring possibilities: virtual reality in nursing research	Res Theory Nurs Pract.;23(2):133–47.	2009

3.2 Medical Education and Training

Virtual worlds are an exciting area offering opportunities in clinical teaching and interventions. Clinicians and academics may approach these emerging opportunities with enthusiasm or scepticism (Kashani, Roberts, Jones, & Kamel Boulos, 2009). Through 3D visualization of massive volumes of information and databases, clinicians and students can understand important physiological principles or basic anatomy (Alcañiz et al., 2000). For instance, VR can be used to explore the organs by "flying" around, behind, or even inside them. In this sense VR can be used both as didactic and experiential educational tools, allowing a deeper understanding of

Fig. 3 Virtual kidney

the interrelationship of anatomical structures that cannot be achieved by any other means, including cadaveric dissection (Fig. 3).

Apart from anatomical training, VR has been used for teaching the skill of performing different tasks like a 12-lead ECG (Jeffries, Woolf, & Linde, 2003). In all these cases, VR simulators allowed the acquisition of the necessary technical skills required for the procedure.

In some cases, VWs were also used for prevention and to provide healthcare information, educate and improve patients' healthcare knowledge (Kamel Boulos & Toth-Cohen, 2009), i.e. the University of Plymouth has tested a Sexual Health SIM in Second Life. The sexual health project in Second Life was aimed to provide education about sexually transmitted infections, prevention of unintended pregnancy and promotion of equalitarian sexual relationships. The University of Plymouth Sexual Health SIM provides a wide variety of educational experiences, including opportunities to test knowledge of sexual health through quizzes and games, web resources integrated within the virtual context and live seminars on sexual health topics. Between 12nd July 2007 and 12th May 2008, the SIM received more than 3350 visitors/avatars.

Other uses of VW (Often done in the Second Life platform) for medical and healthcare education (Danforth, Procter, Heller, Chen, & Johnson, 2009) have been documented in different articles (Beard, Wilson, Morra, & Keelan, 2009; Gorini, Gaggioli, Vigna, & Riva, 2008; Hansen, 2008; Kamel Boulos, Hetherington & Wheeler, 2007; Kamel Boulos, Ramloll, Jones, & Toth-Cohen, 2008).

Fig. 4 Healthinfo Island (Second Life)

Fig. 5 Jefferson occupational therapy education center in Second Life

Second Life has been used for disaster simulation, nursing training (Skiba, 2009), nutrition education, etc., much of which is referenced by one of the primary in-world sources of healthcare information (HealthInfo Island funded by the National Library of Medicine) (Perryman, 2009) (Fig. 4).

Virtual Worlds like Second Life were also used for consumer health and higher education. Thot-Cohen describes the development and evaluation of public exhibits on health and wellness at the Jefferson occupational therapy education center in Second Life (Toth-Cohen, 2009) (Fig. 5) (Table 3).

Table 3 Medical education & training

	Medical education & Training		
Kaltenborn KF, Rienhoff O.	Virtual reality in medicine	Methods Inf Med. Nov;32(5):407–17.	1993
Lefrançois L, Puddington L.	Extrathymic intestinal T-cell development: virtual reality?	Immunol Today. Jan;16(1):16–21.	1995
Völter S, Krämer KL.	Virtual reality in medicine	Radiologe. Sep;35(9):563–8.	1995
Sakurai K.	A survey of virtual reality research: From technology to psychology	Shinrigaku Kenkyu. Oct;66(4):296–309.	1995
Marran L, Schor C.	Multiaccommodative stimuli in VR systems: problems & solutions	Hum Factors. Sep;39(3):382–8.	1997
Ahmed M, Meech JF, Timoney A.	Virtual reality in medicine	Br J Urol. Nov;80 Suppl 3:46–52.	1997
Kaufman DM, Bell W.	Teaching and assessing clinical skills using virtual reality	Stud Health Technol Inform.;39:467–72.	1997
Moline J.	Virtual reality for health care: a survey	Stud Health Technol Inform.;44:3–34.	1997
Riva G.	Virtual reality as assessment tool in psychology	Stud Health Technol Inform.;44:71–9.	1997
Riva G.	Virtual reality in neuroscience: a survey	Stud Health Technol Inform.;58:191–9.	1998
Gobbetti E, Scateni R.	Virtual reality: past, present and future	Stud Health Technol Inform.;58:3–20.	1998
Botella C, Perpiñá C, Baños RM, et. Al.	Virtual reality: a new clinical setting lab	Stud Health Technol Inform.;58:73–81.	1998
Blonde L, Cook JL, Dey J.	Internet use by endocrinologists	Recent Prog Horm Res.;54:1–29; discussion 29–31.	1999
Dzhafarova OA, Donskaia OG, Zubkov AA, et. Al	Virtual reality technology and physiological functions	Vestn Ross Akad Med Nauk.;(10):26–30.	1999
Parham P.	Virtual reality in the MHC	Immunol Rev. Feb;167:5–15.	1999
Lum LG.	T cell-based immunotherapy for cancer: a virtual reality?	CA Cancer J Clin. Mar-Apr;49(2):74–100, 65.	1999
Marescaux J, Mutter D, Soler L, Vix M, Leroy J.	The Virtual University applied to telesurgery: from tele-education to tele-manipulation	Bull Acad Natl Med.;183(3):509–21; discussion 521–2.	1999
Riva G, Bacchetta M, Baruffi M, et. Al.	The use of PC based VR in clinical medicine: the VREPAR projects	Technol Health Care.;7(4):261–9.	1999
Stenzl A, Kölle D, Eder R, Stöger A, et. Al.	Virtual reality of the lower urinary tract in women	Int Urogynecol J Pelvic Floor Dysfunct.;10 (4):248–53.	1999
Hoffman HM.	Teaching and learning with virtual reality	Stud Health Technol Inform.;79:285–91.	2000

(continued)

Table 3 (continued)

	Medical education & Training		
Riva G, Gamberini L.	Virtual reality as telemedicine tool: technology, ergonomics and actual applications	Technol Health Care.;8(2):113–27.	2000
Riva G, Gamberini L.	Virtual reality in telemedicine	Telemed J E Health. Fall;6(3):327–40.	2000
Reznek M, Harter P, Krummel T.	Virtual reality and simulation: training the future emergency physician	Acad Emerg Med. Jan;9(1):78–87.	2002
Nichols S, Patel H.	Health and safety implications of virtual reality: a review of empirical evidence	Appl Ergon. May;33(3):251–71.	2002
Riva G.	Virtual reality for health care: the status of research	Cyberpsychol Behav. Jun;5(3):219–25.	2002
Letterie GS.	How virtual reality may enhance training in obstetrics and gynecology	Am J Obstet Gynecol. Sep;187(3 Suppl): S37–40.	2002
Schultheis MT, Himelstein J, Rizzo AA.	Virtual reality and neuropsychology: upgrading the current tools	J Head Trauma Rehabil. Oct;17(5):378–94.	2002
Tarr MJ, Warren WH.	Virtual reality in behavioral neuroscience and beyond	Nat Neurosci. Nov;5 Suppl:1089–92.	2002
Riva G.	Applications of virtual environments in medicine	Methods Inf Med.;42(5):524–34.	2003
Mantovani F, Castelnuovo G, Gaggioli A, Riva G.	Virtual reality training for health-care professionals	Cyberpsychol Behav. Aug;6(4):389–95.	2003
Beutler LE, Harwood TM.	Virtual reality in psychotherapy training	J Clin Psychol. Mar;60(3):317–30.	2004
Dankelman J, Wentink M, Grimbergen CA, Stassen HG, Reekers J.	Does virtual reality training make sense in interventional radiology? Training skill-, rule- and knowledge-based behavior	Cardiovasc Intervent Radiol. Sep-Oct;27 (5):417–21. Epub 2004 Aug 12.	2004
Choi KS, Sun H, Heng PA.	An efficient and scalable deformable model for virtual reality-based medical applications	Artif Intell Med. Sep;32(1):51–69.	2004
Xiao J, Zhang HX, Liu L.	Application of virtual reality technique in forensic pathology	Fa Yi Xue Za Zhi. May;21(2):146–8.	2005
Lum LG, Padbury JF, Davol PA, Lee RJ.	Virtual reality of stem cell transplantation to repair injured myocardium	J Cell Biochem. Aug 1;95(5):869–74.	2005
Khalifa YM, Bogorad D, Gibson V, et al.	Virtual reality in ophthalmology training	Surv Ophthalmol. May-Jun;51(3):259–73.	2006
Hilty DM, Alverson DC, Alpert JE, Tong L, et al.	Virtual reality, telemedicine, web and data processing innovations in medical and psychiatric education and clinical care	Acad Psychiatry. Nov-Dec;30(6):528–33.	2006
Mohan A, Proctor M.	Virtual reality--a 'play station' of the future. A review of virtual reality and orthopaedics	Acta Orthop Belg. Dec;72(6):659–63.	2006
Chan C, Kepler TB.	Computational immunology--from bench to virtual reality	Ann Acad Med Singapore. Feb;36(2):123–7.	2007
Stetz MC, Thomas ML, Russo MB, Stetz TA, et al.	Stress, mental health, and cognition: a brief review of relationships and countermeasures.	Aviat Space Environ Med. May;78(5 Suppl): B252–60.	2007
Liu W, Wang S, Zhang J, Li D.	Application of virtual reality in medicine	Sheng Wu Yi Xue Gong Cheng Xue Za Zhi. Aug;24(4):946–9.	2007
Banerjee PP, Luciano CJ, Rizzi S.	Virtual reality simulations	Anesthesiol Clin. Jun;25(2):337–48. Review. Erratum in: Anesthesiol Clin. 2007 Sep;25 (3):687.	2007
Jiang HP, Feng H, Dong FP.	The influence of virtual reality both on biology experiment and teaching	Yi Chuan. Dec;29(12):1529–32.	2007
Thorley-Lawson DA, Duca KA, Shapiro M.	Epstein-Barr virus: a paradigm for persistent infection - for real and in virtual reality	Trends Immunol. Apr;29(4):195–201. Epub 2008 Mar 6.	2008
Schmidt B, Stewart S.	Implementing the virtual reality learning environment: Second Life	Nurse Educ. Jul-Aug;34(4):152–5.	2009
Adamovich SV, Fluet GG, Tunik E, Merians AS.	Sensorimotor training in virtual reality: a review.	NeuroRehabilitation.;25(1):29–44.	2009
Desender LM, Van Herzeele I, Aggarwal R, et al.	Training with simulation versus operative room attendance	J Cardiovasc Surg (Torino). Feb;52(1):17–37.	2011
Galvin J, Levac D.,	Facilitating clinical decision-making about the use of virtual reality within paediatric motor rehabilitation: describing and classifying virtual reality systems	Dev Neurorehabil.;14(2):112–22.	2011
Levac DE, Galvin J.	Facilitating clinical decision-making about the use of virtual reality within paediatric motor rehabilitation: application of a classification framework	Dev Neurorehabil.;14(3):177–84.	2011

3.3 *The Surgical Simulation: Neurosurgery, Laparoscopic & Endoscopic, Simulators*

In 1995, Whalley (1995) stated that complex operative techniques can be taught in a virtual reality machine—it is already feasible to use the results of clinical investigations (for example MRI scans) to construct a precise virtual reality model of all or part of a patient. Supercomputers now allow the integration of quite massive databases derived from structural imaging of diseased organs and their simultaneous functional mapping that can be used to give the surgeon the opportunity to rehearse a potentially complex surgical procedure in virtual reality before attempting this with a patient.

Mabrey, Reinig, and Cannon (2010) previous literature review including "virtual reality" AND "surgery" yielded 1025 citations spanning from 1992 to 2009. This subset, VR + Surgery, was then searched using "orthopaedic" OR "orthopedic" OR "fracture" OR "spine" OR "hip" OR "knee" OR "shoulder", yielding 232 articles from 1994 to 2009.

Among the 48 relevant orthopaedic articles from 1995 to 2009 found in the informal literature review, only 23 dealt with specific simulators, with the rest being more general reviews of the topic.

Only 16 of these 23 articles dealt with specific simulators with the rest covering principles of VR training as it related to orthopaedics. They broke down into nine papers about knee arthroscopy simulators (1995–2006), four involving shoulder simulators (1999–2008), and three fractures (2007–2008.) On the other hand, there were 246 citations of laparoscopic virtual reality simulation out of the original 1025 citations (1992–2009).

Gurusamy, Aggarwal, Palanivelu, and Davidson (2008) reviewed 23 randomized control trials of VR laparoscopic simulators that included 612 participants. They reported that VR laparoscopic training decreased the time for task completion and increased overall accuracy in comparison with the controlled subjects who had not undergone VR training. VR technology, when applied to the education of residents in general surgery programs, had a positive impact on their training (Aggarwal et al., 2007; Ahlberg et al., 2007; Grantcharov, Bardram, Funch-Jensen, & Rosenberg, 2003; Larsen et al., 2009; Stefanidis et al., 2005; Verdaasdonk, Dankelman, Lange, & Stassen, 2008).

The number of papers specific to orthopaedics and VR is limited (Mabrey et al., 2010). VR is used effectively in other specialties, especially general surgery. VR simulators are readily available for shoulder and knee arthroscopy but not as well incorporated into training curricula.

One limitation is that VR laparoscopic simulators assess performance, but lack realistic haptic feedback. Augmented Reality (AR) combines a VR setting with real physical materials, instruments, and feedback. Botden and Jakimowicz (2009) present the current developments in Augmented Reality laparoscopic simulation.

The different kinds of simulators used for training purposes are: traditional box trainers, virtual reality (VR), and Augmented Reality (AR) simulators.

- Traditional box trainers have realistic haptic feedback during procedures, but an expert observer must be at disposal to assess the performance.
- VR simulators provide explanations of the tasks to be practised and objective assessment of the performance; however, they lack realistic haptic feedback.
- AR simulators retain realistic haptic feedback and provide objective assessment of the performance of the trainee.

Botden and Jakimowicz (2009) identify four augmented reality laparoscopic simulators:

1. ProMIS: that combines the virtual and real worlds in the same system: users learn, practice and measure their proficiency with real instruments on physical and virtual models (Fig. 6).
2. CELTS (The computer-enhanced laparoscopic training system): that is a prototype laparoscopic surgery simulator that uses real instruments, real video display and laparoscopic light sources with synthetic skin and task trays to permit highly realistic practice of basic surgical skills (Fig. 7).
3. LTS3-e: that is a relatively low-cost augmented reality simulator capable of training and assessing technical laparoscopic skills of the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) Fundamentals of Laparoscopy (FLS) program.

Fig. 6 ProMIS simulator

Fig. 7 CELTS simulator

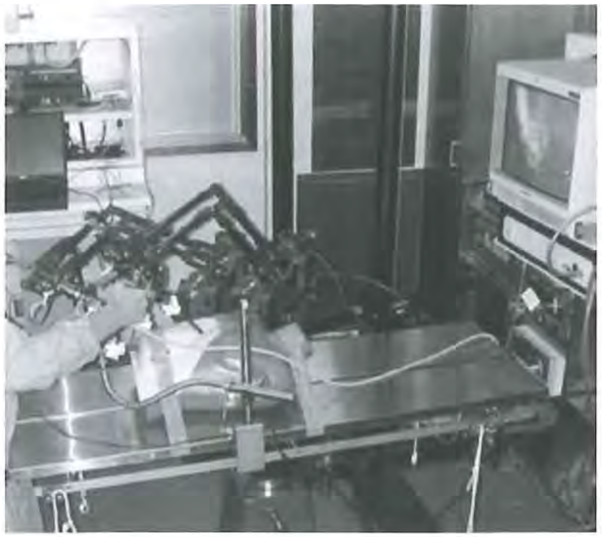


Fig. 8 The Blue Dragon

4. The Blue DRAGON: that is a system for acquiring the kinematics and the dynamics of two endoscopic tools along with the visual view of the surgical scene (Fig. 8).

The AR laparoscopic simulator's major advantage over the VR simulator is that it allows the trainee to use the same instruments that are currently used in the operating theatre. The simulator provides realistic haptic feedback because of the hybrid mannequin environment in which the trainee is working, which is absent in VR systems. This simulator offers a physically realistic training environment that is based on real instruments interacting with real objects.

If we shift our attention from "simulator" to "real surgery" we redefine Augmented Reality (AR) as the process of superimposing live images with synthetic computer-generated images (Marescaux, Diana, & Soler, 2013). AR can serve the surgeon during an operation to highlight anatomical details as a navigation tool. AR may be obtained from preoperative images or in real-time in the operating room. The process to obtain AR includes different phases: (1) generation of a virtual

Fig. 9 Augmented Reality

patient-specific model; (2) visualization of the model in the operative field; (3) registration, which corresponds to an accurate overlaying of the 3D model onto the real patients operative images (Fig. 9).

In his research, Marescaux, used the DICOM format in order to obtain useful datas to render the 3D virtual patient:

(1) Generation of a 3D virtual view of the patient obtained from DICOM format images using mainly two different approaches: Direct Volume Rendering and Surface Rendering. A preoperative exploration of target structures and a simulation of the procedure may be performed on the model. Subsequently, the 3D model is superimposed to the real-time images during the surgical procedure to guide the surgeon throughout the operative strategy and show hidden details using modular transparency.
(2) Direct Volume Rendering (DVR) methods generate images of a 3D volumetric data set without explicitly delineating structures and extracting their surfaces from the medical images (Fig. 10).
(3) Surface Rendering (SR) is a 3D visualization method consisting in a rendering of geometrical meshes which surround the organ's surfaces. A pre-processing of organ delineation, which can be manual, semiautomatic or fully automatic, is required. From this delineation, a colored geometrical mesh is generated automatically and SR allows to visualize it with or without transparency. SR is traditionally used in virtual planning software such as VR-Planning® that

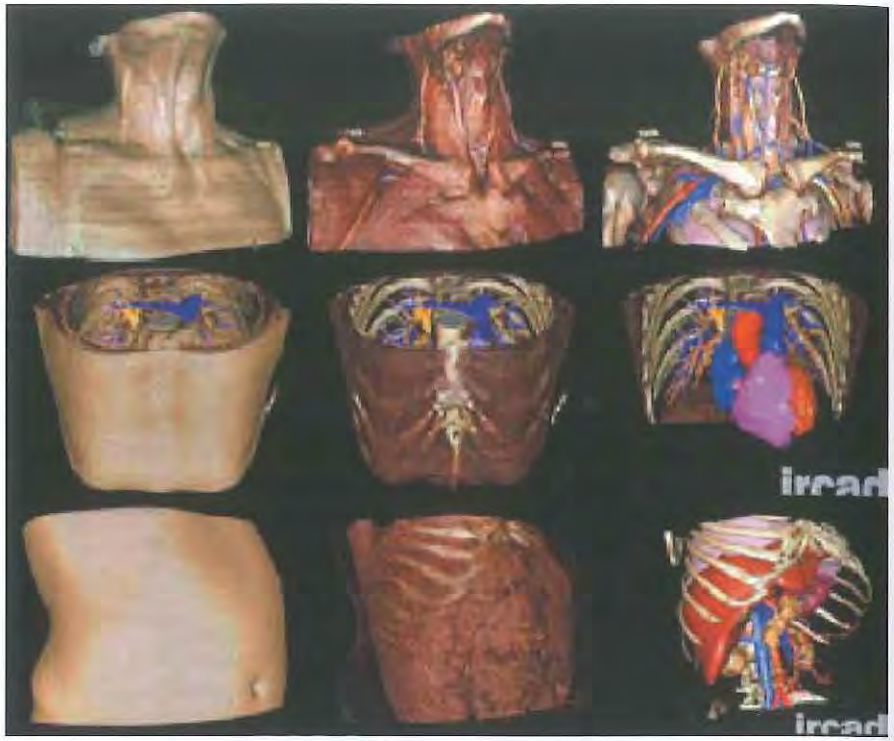


Fig. 10 Direct Volume Rendering

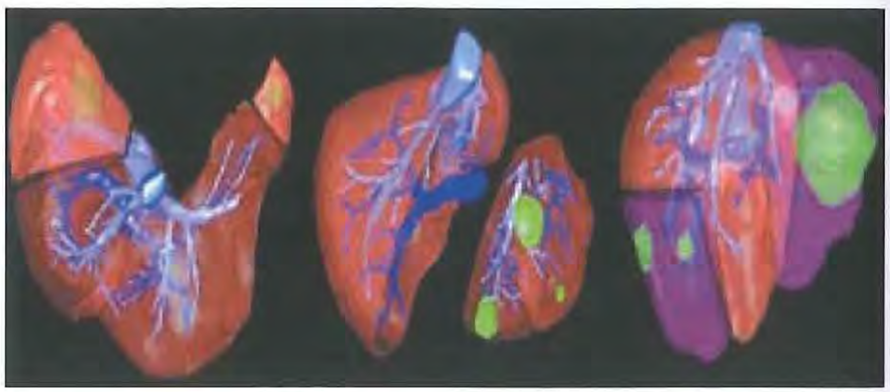


Fig. 11 Rendering

allows virtual navigation, virtual tool positioning, virtual organ resection, and associated resected volume computation (Fig. 11).

(4) Real-time operative images are captured by endoscopic or external cameras and displayed on-screen, and the 3D virtual model is then overlaid with operative

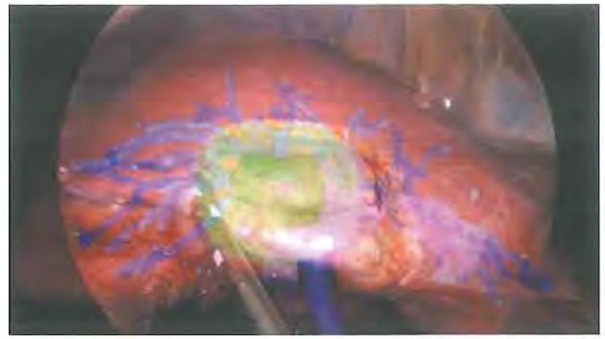


Fig. 12 AR laparoscopic liver tumor resection. AR based on a 3D virtual model obtained from a preoperative MRI of the liver showed a high intraoperative congruence with the real-time ultrasound probe. Liver parenchyma resection was safely accomplished relying on the superimposed tumor and vessel positions

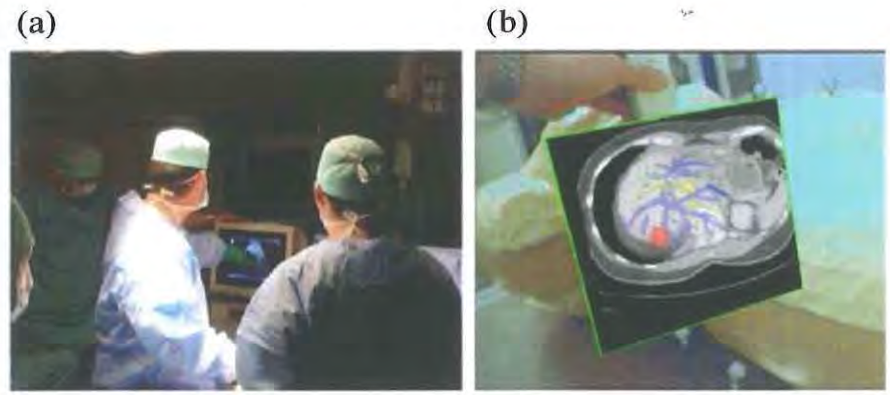


Fig. 13 Overcoming the problem of hand-eye coordination using Augmented Reality. (a) Typical examination using sonography. (b) The AR display enables the user to see the data at the same location where his/her hands operate

images to obtain AR. External static cameras are the cheapest and most effective solution for an external AR view of the patient's internal structures. An alternative solution consists in the use of head-mounted cameras which capture two videos that are displayed in front of the surgeon's eyes through head-mounted display (Fig. 12).

Other main strengths of AR in medical applications is its ability to overcome difficulties related to hand-eye coordination (Johansson, Westling, Backstrom et al., 2001). For example, AR displays are able to present, by means of registration of virtual objects within real world environments, the information exactly where the hands have to act. Figure 13 shows examples of this concept (Lamata et al., 2010).

Another possibility is to bring the support into the "classical" 2D screen, as done in the support of needle ablation of tumours (Table 4).

Table 4 Surgical simulators

			Date
1. Neurosurgery			
Satava RM.	Emerging medical applications of virtual reality: a surgeon's perspective	Artif Intell Med. Aug;6(4):281–8.	1994
Marescaux J, Clément JM, Nord M, Russier Y, Tassetti V, Mutter D, Cotin S, Ayache N.	A new concept in digestive surgery: the computer assisted surgical procedure, from virtual reality to telemanipulation	Bull Acad Natl Med. Nov;181(8):1609–21; discussion 1622–3.	1997
Gorman PJ, Meier AH, Krummel TM.	Simulation and virtual reality in surgical education: real or unreal?	Arch Surg. Nov;134(11):1203–8.	1999
Lange T, Indelicato DJ, Rosen JM.,	Virtual reality in surgical training	Surg Oncol Clin N Am. Jan;9(1):61–79, vii.	2000
Peters TM.	Image-guided surgery: from X-rays to virtual reality	Comput Methods Biomech Biomed Engin.;4 (1):27–57.	2000
Tronnier VM, Staubert A, Bonsanto MM, Wirtz CR, Kunze S.	Virtual reality in neurosurgery	Radiologe. Mar;40(3):211–7.	2000
Meier AH, Rawn CL, Krummel TM.	Virtual reality: surgical application--challenge for the new millennium	J Am Coll Surg. Mar;192(3):372–84.	2001
McCloy R, Stone R.	Science, medicine, and the future. Virtual reality in surgery	BMJ. Oct 20;323(7318):912–5.	2001
Satava RM.	Surgical education and surgical simulation	World J Surg. Nov;25(11):1484–9.	2001
Jackson A, John NW, Thacker NA, Ramsden RT, Gillespie JE, et al.	Developing a virtual reality environment in petrous bone surgery: a state-of-the-art review	Otol Neurotol. Mar;23(2):111–21.	2002
Arnold P, Farrell MJ.	Can virtual reality be used to measure and train surgical skills?	Ergonomics. Apr 15;45(5):362–79.	2002
Spicer MA, Apuzzo ML.	Virtual reality surgery: neurosurgery and the contemporary landscape	Neurosurgery. Mar;52(3):489–97; discussion 496–7.	2003
Balogh A, Preul MC, Schornak M, et al	Intraoperative stereoscopic QuickTime Virtual Reality	J Neurosurg. Apr;100(4):591–6.	2004
Wang P, Becker AA, Jones IA, et al.	A virtual reality surgery simulation of cutting and retraction in neurosurgery with force-feedback	Comput Methods Programs Biomed. 2006 Oct;84(1):11–8. Epub 2006 Aug 30.	2006
Albani JM, Lee DI.	Virtual reality-assisted robotic surgery simulation	J Endourol. Mar;21(3):285–7.	2007
Fried MP, Uribe JI, Sadoughi B.	The role of virtual reality in surgical training in otorhinolaryngology	Curr Opin Otolaryngol Head Neck Surg. Jun;15(3):163–9.	2007
Lemole GM Jr, Banerjee PP, Luciano C, Neckrysh S, Charbel FT.,	Virtual reality in neurosurgical education: part-task ventriculostomy simulation with dynamic visual and haptic feedback	Neurosurgery. Jul;61(1):142–8; discussion 148–9.	2007
Van der Meijden OA, Schijven MP.	The value of haptic feedback in conventional and robot-assisted minimal invasive surgery and virtual reality training: a current review	Surg Endosc. Jun;23(6):1180–90. Epub 2009 Jan 1.	2009
Abdelwahab MG, Cavalcanti DD, Preul MC.	Role of computer technology in neurosurgery	Minerva Chir. Aug;65(4):409–28.	2010
Malone HR, Syed ON, Downes MS, et al.	Simulation in neurosurgery: a review of computer-based simulation environments and their surgical applications	Neurosurgery. Oct;67(4):1105–16.	2010
Palter VN, Grantcharov TP.,	Virtual reality in surgical skills training	Surg Clin North Am. Jun;90(3):605–17.	2010
Lendvay TS.	Surgical simulation in pediatric urologic education	Curr Urol Rep. Apr;12(2):137–43.	2011
2. Laparoscopic & Endoscopic			
Coleman J, Nduka CC, Darzi A.	Virtual reality and laparoscopic surgery	Br J Surg. Dec;81(12):1709–11.	1994
Hart R, Karthigasu K.	The benefits of virtual reality simulator training for laparoscopic surgery	Curr Opin Obstet Gynecol. Aug;19 (4):297–302.	2007
Gurusamy K, Aggarwal R, Palanivelu L, et al.	Systematic review of randomized controlled trials on the effectiveness of virtual reality training for laparoscopic surgery	Br J Surg. Sep;95(9):1088–97.	2008

(continued)

Table 4 (continued)

			Date
Botden SM, Jakimowicz JJ.	What is going on in augmented reality simulation in laparoscopic surgery?	Surg Endosc. Aug;23(8):1693–700. Epub 2008 Sep 24.	2009
Gurusamy KS,Aggarwal R, Palanivelu L, Davidson BR.	Virtual reality training for surgical trainees in laparoscopic surgery	Cochrane Database Syst Rev. Jan 21;(1): CD006575	2009
Mettler LL, Dewan P.	Virtual reality simulators in gynecological endoscopy: a surging new wave	JSLS. Jul-Sep;13(3):279–86.	2009
Thijssen AS, Schijven MP.	Contemporary virtual reality laparoscopy simulators: quicksand or solid grounds for assessing surgical trainees?	Am J Surg. Apr;199(4):529–41. Epub 2010 Jan 18.	2010
Bashir G.	Technology and medicine: the evolution of virtual reality simulation in laparoscopic training	Med Teach.;32(7):558–61.	2010
Van Dongen KW, Ahlberg G, Bonavina L, et al.	European consensus on a competency-based virtual reality training program for basic endoscopic surgical psychomotor skills	Surg Endosc. Jan;25(1):166–71. Epub 2010 Jun 24.	2010
3. Simulators			
Rosen JM, Soltanian H, Laub DR, Mecinski A, Dean WK.	The evolution of virtual reality from surgical training to the development of a simulator for health care delivery. A review.	Stud Health Technol Inform.;29:89–99.	1996
Rodney WM.	Will virtual reality simulators end the credentialing arms race in gastrointestinal endoscopy or the need for family physician faculty with endoscopic skills?	J Am Board Fam Pract. Nov-Dec;11 (6):492–6.	1998
Cosman PH, Cregan PC, Martin CJ, Cartmill JA.	Virtual reality simulators: current status in acquisition and assessment of surgical skills	ANZ J Surg. Jan;72(1):30–4.	2002
Erel E, Aiyenibe B, Butler PE.	Microsurgery simulators in virtual reality: review	Microsurgery.;23(2):147–52.	2003
Schijven M, Jakimowicz J.	Virtual reality surgical laparoscopic simulators	Surg Endosc. Dec;17(12):1943–50. Epub 2003 Oct 28. Review. No abstract available. Erratum in: Surg Endosc. 2003 Dec;17 (12):2041–2.	2003
Carter FJ, Schijven MP, Aggarwal R, et al.	Consensus guidelines for validation of virtual reality surgical simulators	Surg Endosc. 2005 Dec;19(12):1523–32. Epub 2005 Oct 26.	2005
Seymour NE.	VR to OR: a review of the evidence that virtual reality simulation improves operating room performance	World J Surg. 2008 Feb;32(2):182–8.	2008
Fairhurst K, Strickland A, Maddern G.	The LapSim virtual reality simulator: promising but not yet proven	Surg Endosc. 2011 Feb;25(2):343–55. Epub 2010 Jul 8.	2010
4. Other			
Suramo I, Talala T, Karhula V, et al.	Virtual reality in radiology	Duodecim.;113(21):2151–6.	1997
Merril JR.	Using emerging technologies such as virtual reality and the World Wide Web to contribute to a richer understanding of the brain	Ann N Y Acad Sci. May 30;820:229–33.	1997
Shah J, Mackay S, Vale J, Darzi A.	Simulation in urology--a role for virtual reality?	BJU Int. Nov;88(7):661–5.	2001
Cameron BM, Robb RA.	Virtual-reality-assisted interventional procedures	Clin Orthop Relat Res. Jan;442:63–73. Review	2006
Dawson DL.	Virtual reality training for carotid intervention	Nat Clin Pract Neurol. Aug;3(8):470–1.	2007
Neequaye SK, Aggarwal R, Van Herzeele I, et al.	Endovascular skills training and assessment	J Vasc Surg. Nov;46(5):1055–64.	2007
Tsang JS, Naughton PA, Leong S, et al.	Virtual reality simulation in endovascular surgical training	Surgeon. Aug;6(4):214–20.	2008
Onuki T.	Virtual reality in video-assisted thoracoscopic lung segmentectomy	Kyobu Geka. Jul;62(8 Suppl):733–8.	2009
Mabrey JD, Reinig KD, Cannon WD.	Virtual reality in orthopaedics: is it a reality?	Clin Orthop Relat Res. Oct;468(10):2586–91.	2010

3.4 Therapy: (a) Phobias, PTSD, Anxiety Disorders, etc., (b) Rehabilitation, (c) Clinical and Pain Management

In the psychotherapeutic field, VR can also be described as an advanced imaginary system: an experiential form of imagery that is as effective as reality in inducing emotional responses (North, North, & Coble, 1997; Vincelli, Molinari, & Riva, 2001)—indeed in psychotherapy, the change may come through an intense focus on a particular instance or experience (Wolfe, 2002). As outlined by Baños, Botella, and Perpiña (1999) the VR experience can help the course of the therapy for "its capability of reducing the distinction between the computer's reality and the conventional reality". What is more, "VR can be used for experiencing different identities and... even other forms of self, as well". The feeling of "presence" that patients experience in these environments, involving all the sensory motor channels, enables them to really "live" the experience in a more vivid and realistic manner than they could do through their own imagination (Vincelli & Molinari, 1998). This should mean fewer treatment sessions, and, therefore, lower costs for the treatment (Wiederhold, Gevirtz, & Wiederhold, 1998; Wiederhold & Wiederhold, 1998). The first commercial version of a VR system was developed by Morton Heilig in 1956 (Heilig, 1962).

Phobias, PTSD, Anxiety Disorders: VR was verified in the treatment of six psychological disorders: acrophobia (Emmelkamp, Bruynzeel, Drost, & Van der Mast, 2001; Rothbaum et al., 1995), spider phobia (Garcia-Palacios, Hoffman, Carlin, Furness, & Botella, 2002), panic disorders with agoraphobia (Vincelli et al., 2003), body image disturbances (Riva, Bacchetta, Baruffi, & Molinari, 2001), binge eating disorders (Riva, Bacchetta, Baruffi, & Molinari, 2002; Riva, Bacchetta, Cesa, Conti, & Molinari, 2003), and fear of flying (Rothbaum, Hodges, Smith, Lee, & Price, 2000; Wiederhold et al., 2002).

Even if many different kinds of treatment are available for anxiety disorders (Gorini et al., 2008), such as behavioural treatments (relaxation, exposure, modelling and role play), cognitive therapies (thought stopping, mental distraction and thought recording), medication, psychodynamic therapy, support groups in VWs (Norris, 2009), family therapy and biofeedback, many studies have demonstrated that the exposure-based treatments are among the most effective (Deacon & Abramowitz, 2004; Kobak, Greist, Jefferson, Katzelnick, & Henk, 1998). Despite its effectiveness, exposure-based therapy presents significant limitations:

- Many patients are reticent to expose themselves to the real phobic stimulus or situation.
- In vivo exposure can never be fully controlled by the therapist and its intensity can be too strong for the patient (Fig. 14).
- This technique often requires that therapists accompany patients into anxiety-provoking situations in the real world increasing the costs for the patient, and with great time expenditure for both therapist and patient (Gorini et al., 2008).

Fig. 14 Aracnophobia

These are also the reasons why patients usually accept the use of VR very well. In a recent study, Garcia-Palacios, Hoffman, See et al. (2001) compared the acceptance of one-session and multisession in vivo exposure versus multi-session VR exposure therapy. More than 80 % of the sample preferred VR to in vivo exposure.

In psychotherapy, repeated exposure leads patients to consider feared situations less and less threatening and to experience much less frequently feelings of anxiety—accordingly, patients are less inclined to avoid such situations. In the last few years, researchers and clinicians started using VR to carry out a specific form of exposure treatment (VR exposure therapy [VRET]). VRET has the potential to control, enhance and accelerate the treatment process offering several advantages over real exposure or imagination techniques.

Compared with the in vivo exposure, VRET is completely controlled: the quality, intensity and frequency of the exposure is entirely decided by the therapist in the office and can be stopped any time if the patient is unable to tolerate it. The flexibility of VEs also allows the patient to practice in situations often exaggerated and much worse than those that are likely to be encountered in real life (Kashani et al., 2009).

The virtual experience is an "empowering environment" that the therapy provides for patients. As noted by Botella, Perpiña, Baños, and Garcia-Palacios (1998), nothing the patients fear can "really" happen to them in VR. In the cognitive rehabilitation area different case studies and review papers suggest the use of VR in this area (Riva, 1997a, 1997b, 1998a, 1998b; Rizzo & Buckwalter, 1997; Schultheis & Rizzo, 2001) where there are no controlled clinical trials. A better situation can be found in the assessment of cognitive functions in persons with acquired brain injuries. In this area, VR assessment tools are effective and characterized by good psychometric properties (Piron, Cenni, Tonin, & Dam, 2001; Zhang et al., 2001). A typical example of these applications is ARCANA. Using a standard tool (Wisconsin Card Sorting Test—WCST) of neuropsychological assessment as a model, Pugnetti and colleagues have created ARCANA: a virtual building in which the patient has to use environmental clues in the selection of appropriate choices (doorways) to move through the building.

For clinical psychologists and psychiatrists the interaction focus of VR prevails over the simulated one: they use VR to provide a new human–computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but active participants within a computer-generated 3D virtual world (Riva, Rizzo, Alpini et al., 1999; Rizzo, Wiederhold, Riva, & Van Der Zaag, 1998). Starting from 1990, different companies have developed complete VR systems for the treatment of common anxiety disorders and specific phobias, such as: fear of heights, fear of flying, driving phobias, social phobia, fear of public speaking, fear of spiders, panic disorder and PTSD.

Clinical applications in Second Life include also an innovative form of group and personal therapy that uses the online world as a safe training environment for patients with social anxiety disorders and with autistic spectrum disorders, including Asperger syndrome (Biever, 2007). Patients can interact through their avatars in simulated social settings without fearing negative consequences in the real world (Huang, Kamel Boulos, & Dellavalle, 2008).

Two meta-analyses (Parsons & Rizzo, 2008a; Powers & Emmelkamp, 2008) deal with the effectiveness of VR in the psychotherapeutic field. The first demonstrates not only that VRET is more effective than no treatment, but also that it is slightly, but significantly, more effective than in vivo exposure. The other analysis, concerning the affective effects of VRET, suggests that it has a statistically significant effect on all affective domains and that these effects are of the magnitude described in the literature as large (Cohen, 1992).

As to PTSD, the University of Southern California (USC) Institute for Creative Technologies (ICT) created an immersive VRET system for combat-related PTSD. The treatment environment was initially based on recycling virtual assets that were built for the commercially successful X-Box game and tactical training simulation scenario, *Full Spectrum Warrior*. Over the years, other existing and newly created assets developed at the ICT have been integrated into this continually evolving application (Rizzo, Parsons, Lange et al., 2011).

The *Virtual Iraq* application (and the new *Virtual Afghanistan* scenario) consists of a series of virtual scenarios designed to represent relevant contexts for VR exposure therapy, including middle-eastern themed cities and desert road environments (Fig. 15).

Another alternative therapy to typical imaginary exposure treatment for Vietnam combat veterans with PTSD is the VRE (Rothbaum, Hodges, Alarcon et al., 1999). Rothbaum, Hodges, Ready, Graap, & Alarcon (2001) exposed a sample of ten combat veterans with PTSD to two environments: a virtual Huey helicopter flying over a virtual Vietnam and a clearing surrounded by the jungle. All the patients interviewed at the 6-month follow-up reported reductions in PTSD symptoms ranging from 15 to 67 %.

Fig. 15 Virtual Iraq application

Rehabilitation:

A history of encouraging findings from the aviation simulation literature (Hays, Jacobs, Prince, & Salas, 1992) has supported the concept that testing, training and treatment in highly proceduralized VR simulation environments would be a useful direction for psychology and rehabilitation to explore. As an aircraft simulator serves to test and practise piloting abilities under a variety of controlled conditions, VR can be used to create relevant simulated environments where assessment and treatment of cognitive, emotional and motor problems can take place.

Ebavir (Easy Balance Virtual Rehabilitation), for example, is a Wii Balance Board system based on Nintendo's technology (Gil-Gómez et al., 2011). It was designed by clinical therapists to improve, through motivational and adaptive exercises, the standing balance and the posture of patients with Acquired brain injury. The exercises were programmed with a 2D and 3D software creator and has been designed with the help of specialized clinical rehabilitation of balance.

This study aimed at three objectives:

1. Get a valid system for the recovery of the patient.
2. Creation of a system that would strengthen the motivation of patients during the rehabilitation process.
3. Build a system that provides objective data on the evolution of patients (Fig. 16).

Other virtual Reality Exercises have been studied in Stroke Rehabilitation (Saposnik et al., 2010) like the EVREST trial, the first randomized, controlled and in parallel trial and is designed to evaluate the feasibility, safety and efficacy of virtual reality. The trial compared a game of Nintendo Wii to traditional

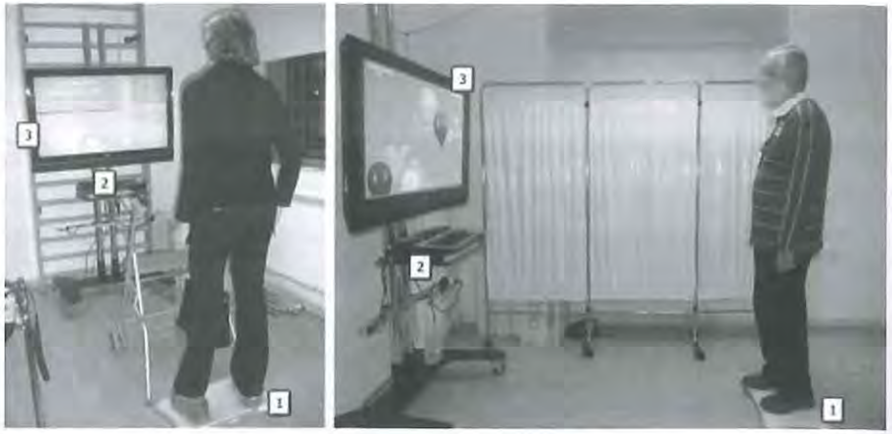


Fig. 16 Ebavir

Fig. 17 Cooking Mama

rehabilitation therapy in order to improve recovery and rehab arm function in stroke patients. The software used were software sports (e.g. the Wii Sports game) and Cooking Mama (a kitchen game) and were sampled 21 patients participating in sessions of 30 min (Fig. 17).

Fig. 18 Octopus

The 3D immersive game "Octopus" was used for rehabilitation after traumatic brain injury (Ustinova, Leonard, Cassavaugh, & Ingersoll, 2011). It has been developed using the software WorldViz Vizard, integrated with the Qualysis for motion analysis. The tracker's participants reproduce the kinematic models of hands in real-time with a high accuracy. The simulated environment was presented in 3D and in a first person view on a screen of 82 inch. Thirteen subjects with mild-to-moderate manifestations of TBI participated in the study. The game was designed to challenge postural stability while trying to reach a moving target (Fig. 18).

In some cases, different authors showed that it is possible to use VR both to induce an illusory perception of a fake limb (Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2009) or a fake hand (Perez-Marcos, Slater, & Sanchez-Vives, 2009) as part of our own body and to produce an out-of-body experience by altering the normal association between touch and its visual correlate. The Oculus Rift[1] can

[1] The Oculus Rift is a virtual reality headset (in its second iteration) made possible by smartphone technologies, developed by Oculus VR, a 2 year-old company recently acquired 2 billions by Facebook. The main target for the Oculus Rift (and commercial focus of Oculus VR) is to provide whole new videogame experiences by building immersive worlds. Being a medical device isn't and probably won't ever be one of their objective; they want to be the next platform, as popular as the smartphone.

Fig. 19 Reconstructed limb with Oculus Rift

allow amputees with Phantom Limb Syndrome to feel "as though their missing limb is still present and even experience itching sensations and the like. By seeing a virtual recreation of that limb, studies have shown that these patients are better able to come to terms with their loss and adapt their brains accordingly". The University of Manchester, tested Oculus Rift in patients with Phantom Limb Syndrome. Using VR, researchers can do more than just mirror the limb like the "traditional mirror box".[2] They can copy the position (so moving the real arm left moves the virtual one left), They can create a set of games rather than just boring exercises and they can easily mirror the legs as well as the arms (Figs. 19 and 20).[3]

Researchers in Vienna are studying the utility of Oculus Rift to better train amputees in the frustrating process of learning how to use prosthetics. Stroke patients "were more likely to improve their arm strength if they played VR games". It is even possible to generate a body transfer illusion: Slater substituted the experience of male subjects' own bodies with a life-sized virtual human female body. It is also possible to use VR to improve body image (Riva, 1998a, 1998b; Riva & Melis, 1997) even in patients with eating disorders (Perpiña et al., 1999; Riva et al., 2002) or obesity (Dean & Cook, 2009; Riva, Bacchetta, Baruffi & Molinari, 2001) (Figs. 21 and 22).

With patients living with "Autism spectrum disorders" (ASD), the realism of the simulated environment allows children to learn important skills, increasing the probability to transfer them into their everyday lives (McComas, Pivik, & Laflamme, 1998; Strickland, 1997) (Fig. 23).

[2] The traditional mirror box has been shown to affect patients in a positive way. The patient places their remaining limb (their left arm, say) into the mirror box. They can then see a reflection of their arm where their missing right arm should be. By performing a set of exercises, studies have shown this can have a beneficial effect.

[3] https://developer.oculusvr.com/forums/viewtopic.php?f=28&t=6207

Fig. 20 Programmer testing software for the Phantom Limb Syndrome

Fig. 21 Body dysmorphic disorder (BDD), or body dysmorphia or dysmorphic syndrome (dysmorphophobia)

The literature is increasingly recognising the potential benefits of VR in supporting the learning process, particularly related to social situations, in children with autism (Ehrlich & Miller, 2009; Goodwin, 2008; Parsons & Mitchell, 2002). Those researches analysed the ability of children with ASD in using VEs, and several studies, except one (Parsons, Mitchell, & Leonard, 2005), suggested that they successfully acquire new pieces of information from VEs. In particular, participants with ASDs learned how to use the equipment quickly and showed significant improvements in performance after a few trials in the VE (Parsons, Mitchell, & Leonard, 2004). Two studies, using desktop VEs as a habilitation tool, have recently been carried out to teach children how to behave in social domains and how to understand social conventions (Herrera et al., 2008; Mitchell, Parsons, & Leonard, 2007). The realism of the simulated environment allows children to learn important skills (Bellani, Fornasari, Chittaro, & Brambilla, 2011), increasing

Fig. 22 Vr and Obesity

Fig. 23 Vr and ADHD—Attention deficit hyperactivity disorder

the probability to transfer them into their everyday lives (McComas et al., 1998; Strickland, 1997; Wang & Reid, 2010).

Pain Management:

The first published report to document VR as an effective analgesic for burn wound care was authored by Hoffman, Doctor, Patterson, Carrougher, and Furness (2000). After this original report, other groups have reported similar analgesic benefits when immersive VR (Chan, Chung, Wong, Lien, & Yang, 2007; Maani, Hoffman, DeSocio et al., 2008) or 'augmented reality' distraction (Mott, Bucolo, Cuttle et al., 2008) is added to standard pharmacologic analgesia for portions of (as opposed to

the entirety of) bedside wound care procedures, although generally with limited numbers of patients.

Numerous reports have also documented the potential analgesic benefit of immersive VR in medical settings ranging from cancer therapy (Gershon, Zimand, Pickering, Rothbaum, & Hodges, 2004; Windich-Biermeier, Sjoberg, Dale, Eshelman, & Guzzetta, 2007) to dental care (Hoffman, Garcia-Palacios, Patterson et al., 2001) to transurethral prostate ablation (Wright, Hoffman, & Sweet, 2005).

The combination of multisensory inputs and interactivity makes the VR experience more immersive and realistic than conventional television or video games, and can successfully capture much of the user's conscious attention (Sharar, Miller, Teeley et al., 2008).

Immersive virtual reality provides a particularly intense form of cognitive distraction during such brief, painful procedures, particularly well-adapted for use in children (Sharar et al., 2008) (Fig. 24).

Mechanistic investigations of VR analgesia in the setting of controlled, experimental pain suggest that the magnitude of analgesic effect is dependent upon the user's sense of 'presence' in the virtual environment (Hoffman, Sharar, Coda et al., 2004), that subjective VR analgesia is accompanied by simultaneous reductions in pain-related brain activity in the cerebral cortex and brainstem (Hoffman, Richards, Coda et al., 2004), and that VR analgesia is of similar magnitude to, and additive with, clinically relevant doses of concurrent systemic opioid analgesics (Hoffman, Richards, Van Oostrom et al., 2007).

A recent report by Sharar, Carrougher, Nakamura et al. (2007) compiled results from three ongoing controlled studies to enhance statistical power and investigate such factors as gender, age and ethnicity. This report includes the largest number of subjects published to date—a total of 146 analgesic comparisons in 88 subjects ranging in age from 6 to 65 years—and found that subjective pain ratings were reduced by 20–37 % with immersive VR during passive range of motion (ROM) therapy.

Furthermore, none of the pain improvements due to VR distraction varied with differences in gender, ethnicity, initial burn size or duration of the therapy session. Interestingly, the authors found that user assessments of both the realness of the

Fig. 24 VR and Pain Management

virtual environment, as well as their sense of presence in the virtual environment, differed by age of subjects, with younger subjects (<19 years old) reporting significantly higher ratings for realness and presence than adult subjects (≥19 years old).

The current understanding of the mechanism(s) by which immersive VR reduces subjective pain is skeletal, and largely based on the assumption that multisensory VR experience is distracting to the user and thereby reduces the amount of conscious attention patients can employ to process and interpret nociceptive inputs arising from painful procedures.

In the Hospital Perpetuo Socorro in collaboration with the University of Las Palmas de Gran Canaria (ULPGC), surgeons found a novel use for the Oculus Rift virtual reality headset. They used it as a means of easing patient anxiety during a knee arthroscopy procedure. Using software developed by Droiders, a Spanish software development company, doctors used the immersive virtual reality headset in easing patient anxiety in the operating room by placing them into a calming, simulated virtual environment.[4]

Clinical:

A short list of areas where Clinical VR has been usefully applied includes fear reduction in persons with simple phobias (Parsons & Rizzo, 2008a, 2008b; Powers & Emmelkamp, 2008), treatment for PTSD (Difede et al., 2007; Difede & Hoffman, 2002; Rizzo, 2010; Rizzo, Difede, Rothbaum, & Reger, 2010; Rothbaum et al. 2001), stress management in cancer patients (Schneider, Kisby, & Flint, 2010), acute pain reduction during wound care and physical therapy with burn patients (Hoffman et al., 2011), body image disturbances in patients with eating disorders (Riva, 2005), navigation and spatial training in children and adults with motor impairments (Rizzo, Schultheis, Kerns, & Mateer, 2004; Stanton, Foreman, & Wilson, 1998), functional skill training and motor rehabilitation with patients having central nervous system dysfunction (e.g., stroke, TBI, SCI, cerebral palsy, multiple sclerosis) (Holden, 2005; Merians et al., 2010), and for the assessment and rehabilitation of attention, memory, spatial skills and other cognitive functions in both clinical and unimpaired populations (Parsons & Rizzo, 2008a, 2008b; Parsons, Rizzo, Rogers, & York, 2009; Rizzo et al., 2006; Rose, Brooks, & Rizzo, 2005). To carry out these studies, VR scientists constructed virtual airplanes, skyscrapers, spiders, battlefields, social settings, beaches, fantasy worlds and the mundane (but highly relevant) functional environments of schoolrooms, offices, homes, streets and supermarkets. In essence, clinicians can now create simulated environments that reproduce the outside world and use them in the clinical setting to immerse patients in simulations that support the aims and mechanics of a specific therapeutic approach (Rizzo et al., 2011).

Optale et al. (1997, 1999) used immersive VR to improve the efficacy of a psychodynamic approach in treating male erectile disorders. In this VE experiment, four different expandable pathways open up through a forest, bringing the patients back into their childhood, adolescence, and teens, when they started to get interested in the opposite sex. Different situations were presented with obstacles that the patient had to overcome to proceed. VR environments were used as a form of controlled dreams allowing the patient to express in a non-verbal way transference reactions and free associations related to his sexual experience (Table 5).

[4] Wiltz, C. (2014). Oculus Rift and Google Glass Augment Surgery at Spanish Hospital. *Research and Development MDDIonline*, July 11, 2014, available on http://www.mddionline.com/article/oculus-rift-and-google-glass-augment-surgery-spanish-hospital-140711

4 Discussion

Examining the available literature that we found in the four search engines considered, we may conclude that VR in medicine could be described as a communication interface based on interactive 3D visualization, able to collect and integrate different inputs and data sets in a single realistic experience.

VR for healthcare is different as to goals and applications from the "Real Virtual World" that is defined as a combination of 3D + 3C (communication, creation and commerce), that is to say a three dimensional world in which communities (Ikegami, 2008) of real people interact, creating content, objects and services and producing real economic value through e-Commerce (Martin, 2008).

All VR's definitions previously discussed underline two different points of view. For physicians and surgeons, the ultimate goal of VR is the presentation of virtual objects to all the human senses in a way identical to their natural counterpart (Székely & Satava, 1999). As noted by Satava and Jones (2002), as more and more of the medical technologies become information-based, it will be possible to represent a patient with such faithfulness that the image may become a surrogate for the patient—the *medical avatar*.

An effective VR system should offer real-like body parts or avatars that interact with external devices such as surgical instruments as near as possible to their real models.

For clinical psychologists and rehabilitation specialists the ultimate goal is radically different (Riva et al., 1999; Rizzo et al., 1998). They use VR to provide a new human-computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but active participants within a computer-generated 3D VW. According to Riva (2005) four barriers still remain in the VR application in Medicine. The first is the lack of standardization in VR devices and software. The PC-based systems, while cheap and easy-to-use, still suffer from a lack of flexibility and capabilities necessary to individualize environments for each patient (Riva, 1997a, 1997b). To date, very few of the various VR systems available are interoperable. This makes their use difficult in contexts other than those in which they are developed. The second is the lack of standardized protocols that can be shared by the community of researchers. Current searches of the two clinical databases used in this review yielded only five published clinical protocols: for the treatment of eating disorders (Riva, Bacchetta, Cesa et al., 2001), fear of flying (Klein, 1999; Rothbaum, Hodges, & Smith, 1999), fear of public speaking (Botella, Baños, Villa et al., 2000), and panic disorders (Vincelli, Choi,

Table 5 Psycotherapy

	Title		Date
1. Psychotherapy: Phobias, PTSD, Anxiety disorders, ecc.			
Bloom RW.	Psychiatric therapeutic applications of virtual reality technology (VRT): research prospectus and phenomenological critique	Stud Health Technol Inform.;39:11–6.	1997
North MM, North SM, Coble JR.	Virtual reality therapy: an effective treatment for psychological disorders	Stud Health Technol Inform.;44:59–70.	1997
Strickland D.	Virtual reality for the treatment of autism	Stud Health Technol Inform.;44:81–6.	1997
Huang MP, Alessi NE.	Current limitations into the application of virtual reality to mental health research	Stud Health Technol Inform.;58:63–6.	1998
Vincelli F, Molinari E.	Virtual reality and imaginative techniques in clinical psychology	Stud Health Technol Inform.;58:67–72.	1998
Ohsuga M, Oyama H.	Possibility of virtual reality for mental care	Stud Health Technol Inform.;58:82–90.	1998
Bullinger AH, Roessler A, Mueller-Spahn F.	From toy to tool: the development of immersive virtual reality environments for psychotherapy of specific phobias	Stud Health Technol Inform.;58:103–11.	1998
North MM, North SM, Coble JR.	Virtual reality therapy: an effective treatment for phobias	Stud Health Technol Inform.;58:112–9.	1998
Rogers MB 2nd.	Virtual reality in psychotherapy: the MYTHSEEKER software	Stud Health Technol Inform.;58:170–9.	1998
Marks I.	Computer aids to mental health care	Can J Psychiatry. Aug;44(6):548–55.	1999
Rothbaum BO, Hodges LF.	The use of virtual reality exposure in the treatment of anxiety disorders	Behav Modif. Oct;23(4):507–25.	1999
Neziroglu F, Hsia C, Yaryura-Tobias JA.	Behavioral, cognitive, and family therapy for obsessive-compulsive and related disorders	Psychiatr Clin North Am. Sep;23(3):657–70.	2000
Davidson J, Smith M.	Bio-phobias/techno-philias: virtual reality exposure as treatment for phobias of 'nature'	Sociol Health Illn. Sep;25(6):644–61.	2003
Anderson P, Jacobs C, Rothbaum BO.	Computer-supported cognitive behavioral treatment of anxiety disorders	J Clin Psychol. Mar;60(3):253–67.	2004
Krijn M, Emmelkamp PM, Olafsson RP, Biemond R.	Virtual reality exposure therapy of anxiety disorders: a review	Clin Psychol Rev. Jul;24(3):259–81.	2004
Riva G.	Virtual reality in psychotherapy: review	Cyberpsychol Behav. Jun;8(3):220–30; discussion 231–40.	2005
Gregg L, Tarrier N.	Virtual reality in mental health : a review of the literature	Soc Psychiatry Psychiatr Epidemiol. May;42(5):343–54. Epub 2007 Mar 12.	2007
Gorini A, Riva G.	Virtual reality in anxiety disorders: the past and the future	Expert Rev Neurother. Feb;8(2):215–33.	2008
Freeman D.	Studying and treating schizophrenia using virtual reality: a new paradigm	Schizophr Bull. Jul;34(4):605–10. Epub 2008 Mar 28.	2008
Reger GM, Gahm GA.	Virtual reality exposure therapy for active duty soldiers	J Clin Psychol. Aug;64(8):940–6.	2008
da Costa RT, Sardinha A, Nardi AE.	Virtual reality exposure in the treatment of fear of flying	Aviat Space Environ Med. Sep;79(9):899–903.	2008
Coelho CM, Waters AM, Hine TJ, Wallis G.	The use of virtual reality in acrophobia research and treatment	J Anxiety Disord. Jun;23(5):563–74. Epub 2009 Feb 10.	2009
Wiederhold BK, Wiederhold MD.	Virtual reality treatment of posttraumatic stress disorder due to motor vehicle accident	Cyberpsychol Behav Soc Netw. Feb;13(1):21–7.	2010
Riva G, Raspelli S, Algeri D, Pallavicini F, et al.	Interreality in practice: bridging virtual and real worlds in the treatment of posttraumatic stress disorders	Cyberpsychol Behav Soc Netw. Feb;13(1):55–65.	2010
De Carvalho MR, Freire RC, Nardi AE.	Virtual reality as a mechanism for exposure therapy	World J Biol Psychiatry. Mar;11(2 Pt 2):220–30.	2010
Gerardi M, Cukor J, Difede J, Rizzo A, Rothbaum BO.	Virtual reality exposure therapy for post-traumatic stress disorder and other anxiety disorders	Curr Psychiatry Rep. Aug;12(4):298–305.	2010
Meyerbröker K, Emmelkamp PM.	Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies	Depress Anxiety. Oct;27(10):933–44.	2010
Spurgeon JA, Wright JH.	Computer-assisted cognitive-behavioral therapy	Curr Psychiatry Rep. Dec;12(6):547–52.	2010
Bouchard S.	Could virtual reality be effective in treating children with phobias?	Expert Rev Neurother. Feb;11(2):207–13.	2011
2. Rehabilitation			
Brochard S, Robertson J, Médée B, Rémy-Néris O.	What's new in new technologies for upper extremity rehabilitation?	Curr Opin Neurol. Dec;23(6):683–7.	2010
Brooks BM, Rose FD.	The use of virtual reality in memory rehabilitation: current findings and future directions	NeuroRehabilitation.;18(2):147–57.	2003

(continued)

Table 5 (continued)

	Title		Date
Buckwalter JG, Rizzo AA.	Virtual reality and the neuropsychological assessment of persons with neurologically based cognitive impairments	Stud Health Technol Inform.;39:17–21.	1997
Burdea GC.	Virtual rehabilitation--benefits and challenges	Methods Inf Med.;42(5):519–23.	2003
Cameirão MS, Bermúdez I Badia S, et al.	The rehabilitation gaming system: a review	Stud Health Technol Inform.;145:65–83.	2009
Cherniack EP.	Not just fun and games: applications of virtual reality in the identification and rehabilitation of cognitive disorders of the elderly	Disabil Rehabil Assist Technol. 2011;6 (4):283–9. Epub Dec 15.	2011
Crosbie JH, Lennon S, Basford JR, McDonough SM.	Virtual reality in stroke rehabilitation: still more virtual than real	Disabil Rehabil. Jul 30;29(14):1139–46; discussion 1147–52.	2007
D'Angelo M, Narayanan S, Reynolds DB, Kotowski S, Page S.	Application of virtual reality to the rehabilitation field to aid amputee rehabilitation: findings from a systematic review	Disabil Rehabil Assist Technol. Jan;5 (2):136–42.	2010
Deutsch JE, Merians AS, Adamovich S, et al.	Development and application of virtual reality technology to improve hand use and gait of individuals post-stroke	Restor Neurol Neurosci.;22(3–5):371–86.	2004
Deutsch JE, Mirelman A.	Virtual reality-based approaches to enable walking for people poststroke	Top Stroke Rehabil. Nov-Dec;14(6):45–53.	2007
Galvin J, McDonald R, Catroppa C, Anderson V.	Does intervention using virtual reality improve upper limb function in children with neurological impairment: a systematic review of the evidence	Brain Inj. 2011;25(5):435–42. Epub Mar 14.	2011
Grealy MA, Heffernan D.	The rehabilitation of brain injured children: the case for including physical exercise and virtual reality.	Pediatr Rehabil. Apr-Jun;4(2):41–9.	2000
Henderson A, Korner-Bitensky N, Levin M.	Virtual reality in stroke rehabilitation: a systematic review of its effectiveness for upper limb motor recovery	Top Stroke Rehabil. Mar-Apr;14(2):52–61.	2007
Holden MK.	Virtual environments for motor rehabilitation: review	Cyberpsychol Behav. Jun;8(3):187–211; discussion 212–9.	2005
Johnson DA, Rose FD, Rushton S, et al.	Virtual reality: a new prosthesis for brain injury rehabilitation	Scott Med J. Jun;43(3):81–3.	1998
Kiryu T, So RH.	Sensation of presence and cybersickness in applications of virtual reality for advanced rehabilitation	J Neuroeng Rehabil. Sep 25;4:34.	2007
Kraft M, Amick MM, Barth JT, French LM, Lew HL.	A review of driving simulator parameters relevant to the Operation Enduring Freedom/Operation Iraqi Freedom veteran population	Am J Phys Med Rehabil. Apr;89(4): 336–44.	2010
Lange B, Flynn SM, Rizzo AA.	Game-based telerehabilitation	Eur J Phys Rehabil Med. Mar;45(1): 143–51. Epub 2009 Mar 12.	2009
Lannen T, Brown D, Powell H.	Control of virtual environments for young people with learning difficulties	Disabil Rehabil. Jul 20-Aug 15;24 (11–12):578–86.	2002
Lucca LF.	Virtual reality and motor rehabilitation of the upper limb after stroke: a generation of progress?	J Rehabil Med. Nov;41(12):1003–100.	2009
McComas J, Pivik J, Laflamme M.	Current uses of virtual reality for children with disabilities	Stud Health Technol Inform.;58:161–9.	1998
Mumford N, Wilson PH.	Virtual reality in acquired brain injury upper limb rehabilitation: evidence-based evaluation of clinical research	Brain Inj. Mar;23(3):179–91.	2009
Parsons S, Mitchell P.	The potential of virtual reality in social skills training for people with autistic spectrum disorders	J Intellect Disabil Res. Jun;46(Pt 5): 430–43.	2002
Parsons TD, Rizzo AA, Rogers S, York P.	Virtual reality in paediatric rehabilitation: a review	Dev Neurorehabil. Aug;12(4):224–38.	2009
Patton J, Dawe G, Scharver C, Mussa-Ivaldi F, Kenyon R.	Robotics and virtual reality: a perfect marriage for motor control research and rehabilitation	Assist Technol. Fall;18(2):181–95.	2006
Riva G, Bolzoni M, Carella F, et al.	Virtual reality environments for psycho-neuro-physiological assessment and rehabilitation	Stud Health Technol Inform.;39:34–45.	1997
Rizzo AA, Buckwalter JG.	The status of virtual reality for the cognitive rehabilitation of persons with neurological disorders and acquired brain injury	Stud Health Technol Inform.;39:22–33.	1997
Rizzo AA, Buckwalter JG.	Virtual reality and cognitive assessment and rehabilitation: the state of the art	Stud Health Technol Inform.;44:123–45.	1997
Rose FD, Attree EA, Brooks BM.	Virtual environments in neuropsychological assessment and rehabilitation	Stud Health Technol Inform.;44:147–55.	1997
Rose FD, Attree EA, Johnson DA.	Virtual reality: an assistive technology in neurological rehabilitation	Curr Opin Neurol. Dec;9(6):461–7.	1996

(continued)

Table 5 (continued)

	Title		Date
Rose FD, Brooks BM, Rizzo AA.	Virtual reality in brain damage rehabilitation: review.	Cyberpsychol Behav. Jun;8(3):241–62; discussion 263–71.	2005
Snider L, Majnemer A, Darsaklis V.	Virtual reality as a therapeutic modality for children with cerebral palsy	Dev Neurorehabil.;13(2):120–8.	2010
Standen PJ, Brown DJ.	Virtual reality in the rehabilitation of people with intellectual disabilities: review	Cyberpsychol Behav. Jun;8(3):272–82; discussion 283–8.	2005
Stanton D, Foreman N, Wilson PN.	Uses of virtual reality in clinical training: developing the spatial skills of children with mobility impairments	Stud Health Technol Inform.;58:219–32.	1998
Tsirlin I, Dupierrix E, Chokron S, Coquillart S, Ohlmann T.	Uses of virtual reality for diagnosis, rehabilitation and study of unilateral spatial neglect: review and analysis	Cyberpsychol Behav. Apr;12(2):175–81.	2009
Wang M, Reid D.	Virtual reality in pediatric neurorehabilitation: attention deficit hyperactivity disorder, autism and cerebral palsy	Neuroepidemiology.;36(1):2–18. Epub 2010 Nov 17.	2011
Wilson PN, Foreman N, Stanton D.	Virtual reality, disability and rehabilitation	Disabil Rehabil. Jun;19(6):213–20.	1997
3. Clinical & Pain Management			
Black PM.	Hormones, radiosurgery and virtual reality: new aspects of meningioma management	Can J Neurol Sci. 1997 Nov;24(4):302–6.	1997
Burridge JH, Hughes AM.,	Potential for new technologies in clinical practice	Curr Opin Neurol. Dec;23(6):671–7.	2010
Burt DE.	Virtual reality in anaesthesia	Br J Anaesth. Oct;75(4):472–80.	1995
Foley L, Maddison R.	Use of active video games to increase physical activity in children: a (virtual) reality?	Pediatr Exerc Sci. Feb;22(1):7–20.	2010
Gaggioli A, Mantovani F, Castelnuovo G, et al.	Avatars in clinical psychology: a framework for the clinical use of virtual humans	Cyberpsychol Behav. Apr;6(2):117–25.	2003
Hoffman HG, Chambers GT, Meyer WJ 3rd, et al.	Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures	Ann Behav Med. 2011 Apr;41(2):183–91.	2011
Hoffman HG, Richards TL, Bills AR, et al.	Using FMRI to study the neural correlates of virtual reality analgesia	CNS Spectr. 2006 Jan;11(1):45–51.	2006
Lange BS, Requejo P, Flynn SM, et al.	The potential of virtual reality and gaming to assist successful aging with disability	Phys Med Rehabil Clin N Am. 2010 May;21(2):339–56.	2010
Leeksma OC, Kessler JH, Huijbers IJ, Ten Bosch GJ, Melief CJ.	BCR-ABL directed immunotherapy: a virtual reality?	Leuk Lymphoma. 2000 Jun;38(1–2):175–81.	2000
Lewis CH, Griffin MJ.	Human factors consideration in clinical applications of virtual reality	Stud Health Technol Inform. 1997;44:35–56.	1997
Mahrer NE, Gold JI.	The use of virtual reality for pain control: a review	Curr Pain Headache Rep. 2009 Apr;13(2):100–9.	2009
Malloy KM, Milling LS.	The effectiveness of virtual reality distraction for pain reduction: a systematic review	Clin Psychol Rev. 2010 Dec;30(8):1011–8. Epub 2010 Jul 13.	2010
Morris LD, Louw QA, Grimmer-Somers K.	The effectiveness of virtual reality on reducing pain and anxiety in burn injury patients: a systematic review	Clin J Pain. 2009 Nov-Dec;25(9):815–26.	2009
Nakano S, Yorozuya K, Takasugi M, Mouri Y, Fukutomi T, Mitake T.	Real-time virtual sonography (RVS): a new virtual reality technique for detection of enhancing lesions on contrast-enhanced MR imaging of the breast by using sonography	Nihon Rinsho. 2007 Jun 28;65 Suppl 6:304–9.	2007
Oyama H.	Virtual reality for the palliative care of cancer	Stud Health Technol Inform. 1997;44:87–94.	1997
Peñasco-Martín B, de los Reyes-Guzmán A, Gil-Agudo Á, et al.	Application of virtual reality in the motor aspects of neurorehabilitation	Rev Neurol. 2010 Oct 16;51(8):481–8.	2010
Plancher G, Nicolas S, Piolino P.	Contribution of virtual reality to neuropsychology of memory: study in aging	Psychol Neuropsychiatr Vieil. 2008 Mar;6(1):7–22.	2008
Rovetta A, Lorini F, Canina MR.	Virtual reality in the assessment of neuromotor diseases: measurement of time response in real and virtual environments	Stud Health Technol Inform. 1997;44:165–84.	1997
Sharar SR, Miller W, Teeley A, et al.	Applications of virtual reality for pain management in burn-injured patients	Expert Rev Neurother. 2008 Nov;8(11):1667–74.	2008
Steffin M.	Computer assisted therapy for multiple sclerosis and spinal cord injury patients application of virtual reality	Stud Health Technol Inform. 1997;39:64–72.	1997
Virk S, McConville KM.	Virtual reality applications in improving postural control and minimizing falls	Conf Proc IEEE Eng Med Biol Soc. 2006;1:2694–7.	2006
Wismeijer AA, Vingerhoets AJ.	The use of virtual reality and audiovisual eyeglass systems as adjunct analgesic techniques: a review of the literature	Ann Behav Med. 2005 Dec;30(3):268–78. Review	2005

Molinari et al., 2001). The third barrier is the cost required for the set-up of these protocols' trial.

Finally, the introduction of patients and clinicians to virtual environments raises particular safety and ethical issues (Durlach & Mavor, 1995). Despite developments in VR technology, some users still experience health and safety problems associated with VR use. It is however true that for a large proportion of VR users, these effects are mild and subside quickly (Nichols & Patel, 2002). According to Kennedy, Lane, Berbaum, and Lilienthal (1993) the temporary side effects can be divided into three classes of symptoms related to the sensory conflicts and to the use of virtual reality equipment: (1) visual symptoms (eyestrains, blurred vision, headaches), (2) disorientation (vertigo, imbalance) and (3) nausea (vomiting, dizziness).

We also have to consider two critical aspects of this review: 1. We have taken into consideration only 4 search engines without considering other psychology search engines like APA (PsycINFO, PsycARTICLES, PsycBOOKS, PsycCRITIQUES, PsycEXTRA, PsycTHERAPY, etc.). 2. The key terms we selected are not completely descriptive for the entire world of virtual healthcare application.

But it is important to underline that Virtual worlds are an exciting area offering opportunities in every healthcare areas, from teaching to clinical interventions. We can assume this field of study will offer great opportunities in the world of e-learning and simulators. If we think about Augmented Reality application to glass, it is clear that it could be a very important tool in operating theatre or just for teaching. We may imagine that it could be useful for video sharing and storage—physicians could record medical visits and store them for future reference or share the footage with other doctors. Moreover, it could be employed for diagnostic reference: if glass is integrated with an electronic medical record (EMR), it could provide a real-time feed of the patient's vital signs.

We could also imagine other uses, such as:

- A textbook alternative: rather than referring to a medical textbook, physicians can perform a search on the fly with their augmented reality glass.
- Emergency room/war zone care: dealing with wounded patients and right there in their field of vision, if they're trying to do any kind of procedure, they'll have step-by-step instructions walking them through it. In trauma situations, doctors need to keep their hands free.
- Helping medical students learn: a surgeon might live stream a live—and potentially rare—surgery to residents and students.
- Preventing medical errors: with an electronic medical record integration, a nurse can scan the medication to confirm whether the drug dose is correct and administered to the right patient.
- Surgery (that is evolving towards a safer minimally invasive approach) could be driven by an augmented reality systems that support surgeons' orientation and improve their accuracy, like the example of the "Resection Map" for the support of hepatectomies.[5]
- Another big area of impact is mental health, where truly immersive VR could be a boon to treating anxieties and fears—from acrophobia (heights) to arachnophobia (spiders) to glossophobia (public speaking)—by carefully exposing patients to digital recreations of the things they fear most.
- Anesthesia's application[6]: in one case, a patient at Hospital Perpetuo Socorro in Alicante, Spain, she opted for local anesthesia—rather than the general anesthesia she'd initially requested—when it was shown to her that virtual reality could help ease her anxiety. Clinical tests have even shown that it can effect decreases in blood pressure and heart rate.
- Medical training application: the 3-D, immersive properties could enhance or substitute for schooling in the medical fields, continuing education and in-service workshops; augmentation for telemedicine encounters; surgical simulations and assorted other applications – from helping with autism (virtual reality can help kids learn social cues and fine-tune motor skills) to palliative care (VR could offer the permanently disabled and terminally ill the opportunity to once again experience a degree of normality).
- Virtual reality could help isolated patient in having relationship with friends and family.
- VR could help child that need hospital care in having live-lessons with his/her classroom.
- And so on...

References

Aggarwal, R., Ward, J., Balasundaram, I., Sains, P., Athanasiou, T., & Darzi, A. (2007). Proving the effectiveness of virtual reality simulation for training in laparoscopic surgery. *Annals of Surgery, 246*, 771–779.

Ahlberg, G., Enochsson, L., Gallagher, A. G., Hedman, L., Hogman, C., & McClusky, D. A. (2007). Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. *American Journal of Surgery, 193*, 797–804.

[5] There are some others AR prototypes like the Endoclamp Positioning System and the ARIS*ER RFA system, with a great potential to reduce errors and increase safety in minimally invasive surgery heart clamping and needle ablations/biopsies respectively.

[6] *"After introducing Oculus Rift virtual reality glasses into the operating theatre for the first time, the traumatic feeling that the patient experiences is improved" according to a statement released by the hospital "This way, we can achieve full immersion in a virtual world that keeps the patient away from the sounds and lights of an operating room and takes him to a relaxing world, very different from the present"*. Miliard, M. (2014) What can Oculus Rift do for healthcare? *Healthcare IT News*, August 7, 2014. Available on: http://m.healthcareitnews.com/news/what-can-oculus-rift-do-healthcare

Alcañiz, M., Perpiña, C., Baños, R., Lozano, J. A., Montesa, J., Botella, C., et al. (2000). A new realistic 3D body representation in virtual environments for the treatment of disturbed body image in eating disorders. *CyberPsychology and Behavior, 3*(3), 421–432.

Baños, R. M., Botella, C., & Perpiña, C. (1999). Virtual reality and psychopathology. *CyberPsychology & Behavior, 2*, 283–292.

Beard, L., Wilson, K., Morra, D., & Keelan, J. (2009). A survey of health-related activities on Second Life. *Journal of Medical Internet Research, 11*(2), e17.

Bellani, M., Fornasari, L., Chittaro, L., & Brambilla, P. (2011). Virtual reality in autism: State of the art. *Epidemiology and Psychiatric Sciences, 20*(3), 235–238.

Biever, C. (2007). Web removes social barriers for those with autism. *New Scientist, 2610*, 26–27.

Botden, S. M. B. I., & Jakimowicz, J. J. (2009). What is going on in augmented reality simulation in laparoscopic surgery? *Surgical Endoscopy, 23*, 1693–1700.

Botella, C., Baños, R. M., Villa, H., et al. (2000). Telepsychology: Public speaking fear treatment on the internet. *CyberPsychology and Behavior, 3*, 959–968.

Botella, C., Perpiña, C., Baños, R. M., & Garcia-Palacios, A. (1998). Virtual reality: A new clinical setting lab. *Studies in Health Technology and Informatics, 58*, 73–81.

Chan, E. A., Chung, J. W., Wong, T. K., Lien, A. S., & Yang, J. Y. (2007). Application of a virtual reality prototype for pain relief of pediatric burn in Taiwan. *Journal of Clinical Nursing, 16*(4), 786–793.

Cheng, Y., & Ye, J. (2010). Exploring the social competence of students with autism spectrum conditions in a collaborative virtual learning environment—The pilot study. *Computers & Education, 54*, 1068–1077.

Chinnock, C. (1994). Virtual reality in surgery and medicine. *Hospital Technology Series, 13*(18), 1–48.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159.

Danforth, D. R., Procter, M., Heller, R., Chen, R. & Johnson, M. (2009). Development of virtual patient simulations for medical education. *Journal For Virtual Worlds Research, 2*(2), 4–11

Deacon, B. J., & Abramowitz, J. S. (2004). Cognitive and behavioral treatments for anxiety disorders: A review of meta-analytic findings. *Journal of Clinical Psychology, 60*(4), 429–441.

Dean, E., & Cook, S. (2009). Does this avatar make me look fat? Obesity and interviewing in Second Life. *Journal of Virtual Worlds Research, 2*(2), 3–11.

Difede, J., Cukor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., et al. (2007). Virtual reality exposure therapy for the treatment of posttraumatic stress disorder following September 11, 2001. *Journal of Clinical Psychiatry, 68*, 1639–1647.

Difede, J., & Hoffman, H. G. (2002). Virtual reality exposure therapy for world trade center post-traumatic stress disorder: A case report. *Cyberpsychology and Behavior, 5*, 529–535.

Durlach, N. I., & Mavor, A. S. E. (1995). *Virtual reality: Scientific and technological challenges*. Washington, DC: National Academy Press. Retrieved from http://www.nap.edu/books/0309051355/html/index.html.

Ehrlich, J. A., & Miller, J. R. (2009). A virtual environment for teaching social skills: AViSSS. *IEEE Computer Graphics and Applications, 29*, 10–16.

Emmelkamp, P. M., Bruynzeel, M., Drost, L., & Van der Mast, C. A. (2001). Virtual reality treatment in acrophobia: A comparison with exposure in vivo. *CyberPsychology & Behavior, 4* (3), 335–339.

Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness, T. A., & Botella, C. (2002). Virtual reality in the treatment of spider phobia: A controlled study. *Behavior Research and Therapy, 40*(9), 983–993.

Garcia-Palacios, A., Hoffman, H. G., See, S. K., et al. (2001). Redefining therapeutic success with virtual reality exposure therapy. *CyberPsychology & Behavior, 4*, 341–348.

Gershon, J., Zimand, E., Pickering, M., Rothbaum, B. O., & Hodges, L. (2004). A pilot and feasibility study of virtual reality as a distraction for children with cancer. *Journal of the American Academy of Child and Adolescent Psychiatry, 43*(10), 1243–1249.

Gil-Gómez et al. (2011). Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: A pilot randomized clinical trial in patients with acquired brain injury. *Journal of NeuroEngineering and Rehabilitation*, 8:30. Open Access: http://www.jneuroengrehab.com/content/8/1/30/

Gonzalez, V. G. (2009). Towards a virtual doctor-patient relationship: Understanding virtual patients. *Journal of Virtual Worlds Research*, 2(2).

Goodwin, M. S. (2008). Enhancing and accelerating the pace of autism research and treatment. *Focus on Autism and Other Developmental Disabilities, 23*, 125–128.

Gorini, A., Gaggioli, A., Vigna, C., & Riva, G. (2008). A Second Life for eHealth: Prospects for the use of 3-D Virtual Worlds in clinical psychology. *Journal of Medical Internet Research, 10*(3), e21.

Gorini, A., Gaggioli, A., & Riva, G. (2007). Virtual worlds, real healing. *Science, 318*(5856), 1549.

Gorini, A., & Riva, G. (2005). Virtual reality in anxiety disorders: The past and the future. *Expert Review of Neurotherapeutics, 8*(2), 215–233.

Grantcharov, T. P., Bardram, L., Funch-Jensen, P., & Rosenberg, J. (2003). Learning curves and impact of previous operative experience on performance on a virtual reality simulator to test laparoscopic surgical skills. *American Journal of Surgery, 185*, 146–149.

Gurusamy, K., Aggarwal, R., Palanivelu, L., & Davidson, B. R. (2008). Systematic review of randomized controlled trials on the effectiveness of virtual reality training for laparoscopic surgery. *The British Journal of Surgery, 95*, 1088–1097.

Hansen, M. (2008). Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: A review of the literature. *Journal of Medical Internet Research, 10*(3), e26.

Hays, R. T., Jacobs, J. W., Prince, C., & Salas, E. (1992). Requirements for future research in flight simulation training: Guidance based on a meta-analytic review. *International Journal of Aviation Psychology, 2*, 143–158.

Heilig, M. (1962) *Sensorama simulator, U.S. Patent No. US3050870 A*. Washington, DC: U.S. Patent and Trademark Office. Retrieved from http://www.google.com/patents?hl=en&lr=&vid=USPAT3050870&id=wOpfAAAAEBAJ&oi=fnd&dq=Heilig,+M.+(1962)+Sensorama+simulator&printsec=abstract#v=onepage&q=Heilig%2C%20M.%20(1962)%20Sensorama%20simulator&f=false

Herrera, G., Alcantud, F., Jordan, R., Blanquer, A., Labajo, G., & De Pablo, C. (2008). Development of symbolic play through the use of virtual reality tools in children with autistic spectrum disorders. *Autism, I*, 143–157.

Hoffman, H. G., Chambers, G. T., Meyer, W. J., Araceneaux, L. L., Russell, W. J., Seibel, E. J., et al. (2011). Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures. *Annals of Behavioral Medicine, 41*(2), 183–191.

Hoffman, H. G., Doctor, J. N., Patterson, D. R., Carrougher, G. J., & Furness, T. A., 3rd. (2000). Virtual reality as an adjunctive pain control during burn wound care in adolescent patients. *Pain, 85*(1–2), 305–309.

Hoffman, H. G., Garcia-Palacios, A., Patterson, D. R., et al. (2001). The effectiveness of virtual reality for dental pain control: A case study. *Cyberpsychology & Behavior, 4*(4), 527–535.

Hoffman, H. G., Richards, T. L., Coda, B., et al. (2004). Modulation of thermal pain-related brain activity with virtual reality: Evidence from fMRI. *Neuroreport, 15*(8), 1245–1248.

Hoffman, H. G., Richards, T. L., Van Oostrom, T., et al. (2007). The analgesic effects of opioids and immersive virtual reality distraction: Evidence from subjective and functional brain imaging assessments. *Anesthesia & Analgesia, 105*(6), 1776–1783.

Hoffman, H. G., Sharar, S. R., Coda, B., et al. (2004). Manipulating presence influences the magnitude of virtual reality analgesia. *Pain, 111*(1–2), 162–168.

Holden, M. K. (2005). Virtual environments for motor rehabilitation: Review. *Cyberpsychology and Behavior, 8*, 187–211.

Huang, S. T., Kamel Boulos, M. N., & Dellavalle, R. P. (2008). Scientific discourse 2.0. *EMBO Reports, 9*(6), 496–499.

Ijsselsteijn, W. A., Lombard, M., & Freeman, J. (2001). Toward a core bibliography of presence. *Cyberpsychology & Behavior, 4*(2), 317–321.

Ikegami, E. (2008). Avatars are for real: Virtual communities and public spheres. *Journal of Virtual Worlds Research, 1*(1), 4–19.

ISO/IEC FCD 19774:200x, *Humanoid animation (H-Anim). Information technology—Computer graphics and image processing*—Humanoid animation (H-Anim). Retrieved from http://h-anim.org/Specifications/H-Anim200x/ISO_IEC_FCD_19774

Jeffries, P., Woolf, S., & Linde, B. (2003). Technology based vs. traditional instruction. A comparison of two methods for teaching the skill of performing a 12-lead ECG. *Nursing Education Perspectives, 24*(2), 70–74.

Johansson, R. S., Westling, G., Backstrom, A., et al. (2001). Eye-hand coordination in object manipulation. *Journal of Neuroscience, 21*(17), 6917–6932. 1529–2401.

Kamel Boulos, M. N. (2009). Novel Emergency/public health situation rooms and more using 4-D GIS. In *ISPRS WG IV/4 International workshop on Virtual Changing Globe for Visualisation & Analysis (VCGVA2009)*. Wuhan University, Wuhan, Hubei, China, 27–28 October, ISPRS Archive.

Kamel Boulos, M. N., & Burden, D. (2007). Web GIS in practice V: 3-D interactive and real-time mapping in Second Life. *International Journal of Health Geographics, 6*, 51.

Kamel Boulos, M. N., Hetherington, L., & Wheeler, S. (2007). Second Life: An overview of the potential of 3-D virtual worlds in medical and health education. *Health Information and Libraries Journal, 24*, 233–245.

Kamel Boulos, M. N., Ramloll, R., Jones, R., & Toth-Cohen, S. (2008). Web 3D for public, environmental and occupational health: Early examples from Second Life. *International Journal of Environmental Research and Public Health, 5*, 290–317.

Kamel Boulos, M. N., & Toth-Cohen, S. (2009). The University of Plymouth sexual health SIM experience in Second Life: Evaluation and reflections after 1 year. *Health Information and Libraries Journal, 26*, 279–288.

Kashani, R. M., Roberts, A., Jones, R. & Kamel Boulos, M. N. (2009). Virtual worlds, collective responses and responsibilities in health. *Journal of Virtual Worlds Research*, *2*(2), 4–7.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology, 3*(3), 203–220.

Klein, R. A. (1999). Treating fear of flying with virtual reality exposure therapy. In L. VandeCreek & T. L. Jackson (Eds.), *Innovations in clinical practice: A source book* (Vol. 17, pp. 449–465). Sarasota, FL: Professional Resource Press.

Kobak, K. A., Greist, J. H., Jefferson, J. W., Katzelnick, D. J., & Henk, H. J. (1998). Behavioral versus pharmacological treatments of obsessive compulsive disorder: A meta-analysis. *Psychopharmacology (Berl.), 136*(3), 205–216.

Lamata, P., Ali, W., Cano, A., Cornella, J., Declerck, J., & Elle, O. J., et al. (2010). *Augmented reality for minimally invasive surgery: Overview and some recent advances*, Augmented reality, Soha Maad (Ed.), ISBN: 978-953-7619-69-5, InTech, Retrieved from http://www.intechopen.com/books/augmented-reality/augmented-reality-for-minimally-invasive-surgeryoverview-and-some-recent-advances

Larsen, C. R., Soerensen, J. L., Grantcharov, T. P., Dalsgaard, T., Schouenborg, L., Ottosen, C., et al. (2009). Effect of virtual reality training on laparoscopic surgery: Randomised controlled trial. *British Medical Journal, 338*, b1802. doi:10.1136/bmj.b1802.

Maani, C., Hoffman, H. G., DeSocio, P. A., et al. (2008). Pain control during wound care for combat-related burn injuries using custom articulated arm mounted virtual reality goggles. *The Journal of Cybertherapy and Rehabilitation, 1*(2), 193–198.

Mabrey, J. D., Reinig, K. D., & Cannon, W. D. (2010). Virtual reality in orthopaedics, is it a reality? *Clinical Orthopaedics and Related Research, 468*, 2586–2591.

Madden, M., Fox, S. (2006). Finding answers online in sickness and in health. *Pew Internet & American Life Project Report*. Retrieved from http://www.pewinternet.org/PPF/r/183/report_display.asp

Marescaux, J., Diana, M., & Soler, L. (2013, May 21). Augmented reality and minimally invasive surgery. *Journal of Gastroenterology and Hepatology Research, 2*(5), 555–560.

Martin, J. (2008). Consuming code: Use-value, exchange-value, and the role of virtual goods in Second Life. *Journal of Virtual Worlds Research, 1*(2), 2–21.

McComas, J., Pivik, J., & Laflamme, M. (1998). Current uses of virtual reality for children with disabilities. *Studies in Health Technology and Informatics, 58*, 161–169.

Merians, A. S., Fluet, G. G., Qiu, Q., Saleh, S., Lafond, I. & Adamovich, S. V. (2010). Integrated arm and hand training using adaptive robotics and virtual reality simulations. In *Proceedings of the 2010 international conference on disability. Virtual Reality and Associated Technology* (pp. 213–222).

Mitchell, P., Parsons, S., & Leonard, A. (2007). Using virtual environments for teaching social understanding to 6 adolescents with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 589–600.

Moore, D., Cheng, Y., McGrath, P., & Powell, N. J. (2005). Collaborative virtual environment technology for people with autism. *Focus on Autism and Other Developmental Disorders, 20*, 231–243.

Mott, J., Bucolo, S., Cuttle, L., et al. (2008). The efficacy of an augmented virtual reality system to alleviate pain in children undergoing burns dressing changes: A randomized controlled trial. *Burns, 34*, 803–808.

Nichols, S., & Patel, H. (2002). Health and safety implications of virtual reality: A review of empirical evidence. *Applied Ergonomics, 33*, 251–271.

Norris, J. (2009). The growth and direction of healthcare support groups in virtual worlds. *Journal of Virtual Worlds Research, 2*(2), 4–20. Retrieved from https://journals.tdl.org/jvwr/index.php/jvwr/article/download/658/500%2B%26cd=2%26hl=it%26ct=clnk%26gl=it.

North, M. M., North, S. M., & Coble, J. R. (1997). Virtual reality therapy for fear of flying. *American Journal of Psychiatry, 154*, 130.

Optale, G., Chierichetti, F., Munari, A., et al. (1999). PET supports the hypothesized existence of a male sexual brain algorithm which may respond to treatment combining psychotherapy with virtual reality. *Studies in Health Technology and Informatics, 62*, 249–251.

Optale, G., Munari, A., Nasta, A., et al. (1997). Multimedia and virtual reality techniques in the treatment of male erectile disorders. *International Journal of Impotence Research, 9*, 197–203.

Parsons, S., & Mitchell, P. (2002). The potential of virtual reality in social skills training for people with autistic spectrum disorders. *Journal of Intellectual Disability Research, 46*, 430–443.

Parsons, S., Mitchell, P., & Leonard, A. (2004). The use and understanding of virtual environments by adolescents with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 34*, 449–466.

Parsons, S., Mitchell, P., & Leonard, A. (2005). Do adolescents with autistic spectrum disorders adhere to social conventions in virtual environments? *Autism, 9*, 95–117.

Parsons, T. D., & Rizzo, A. A. (2008a). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*, 250–261.

Parsons, T. D., & Rizzo, A. A. (2008b). Initial validation of a virtual environment for assessment of memory functioning: Virtual reality cognitive performance assessment test. *Cyberpsychology and Behavior, 11*, 17–25.

Parsons, T. D., Rizzo, A. A., Rogers, S. A., & York, P. (2009). Virtual reality in pediatric rehabilitation: A review. *Developmental Neurorehabilitation, 12*, 224–238.

Perez-Marcos, D., Slater, M., & Sanchez-Vives, M. V. (2009). Inducing a virtual hand ownership illusion through a brain-computer interface. *Neuroreport, 20*(6), 589–594.

Perpiña, C., Botella, C., Baños, R., Marco, J., Alcañiz, M., & Quero, S. (1999). Body image and virtual reality in eating disorders: Is exposure by virtual reality more effective than the classical body image treatment? *Cyberpsychology Behavior, 2*(2), 149–155.

Perryman, C. (2009). *Health info island blog*. Retrieved from http://healthinfoisland.blogspot.com/from

Piron, L., Cenni, F., Tonin, P., & Dam, M. (2001). Virtual Reality as an assessment tool for arm motor deficits after brain lesions. *Studies in Health Technology and Informatics, 81*, 386–392.

Powers, M. B., & Emmelkamp, P. M. (2008). Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of Anxiety Disorders, 22*(3), 561–569. Epub 2007.

Powers, M., & Emmelkamp, P. M. G. (2008). Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of Anxiety Disorders, 22*, 561–569.

Riva, G. (1997a). *Virtual reality in neuro-psychophysiology: Cognitive, clinical and methodological issues in assessment and rehabilitation*. Amsterdam: IOS Press. Retrieved from http://www.cybertherapy.info/pages/book1.htm.

Riva, G. (Ed.). (1997b). *Virtual reality in neuro-psycho-physiology: Cognitive, clinical and methodological issues in assessment and rehabilitation*. Amsterdam: IOS Press. Retrieved from http://www.cybertherapy.info/pages/book1.htm.

Riva, G. (1998a). Virtual environment for body-image modification: Virtual reality system for the treatment of body image disturbances. *Computers in Human Behavior, 14*(3), 477–490.

Riva, G. (1998b). Virtual environments in neuroscience. *IEEE Transactions on Information Technology in Biomedicine, 2*(4), 275–281.

Riva, G. (2003). Application of virtual environments in medicine. *Methods of Information in Medicine, 42*, 524–534.

Riva, G. (2005). Virtual reality in psychotherapy: Review. *Cyberpsychology & Behavior, 8*(3), 220–240.

Riva, G., Anguera, M. T., Wiederhold, B. K. & Mantovani, F. (Eds.). (2006). *From communication to presence: Cognition, emotions and culture towards the ultimate communicative experience*. Amsterdam: Festschrift in honor of Luigi Anolli IOS Press. Retrieved from http://www.emergingcommunication.com

Riva, G., Bacchetta, M., Baruffi, M., & Molinari, E. (2001). Virtual reality-based multidimensional therapy for the treatment of body image disturbances in obesity: A controlled study. *Cyberpsychology and Behavior, 4*(4), 511–526.

Riva, G., Bacchetta, M., Baruffi, M., & Molinari, E. (2002). Virtual-reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: A preliminary controlled study. *IEEE Transactions on Information Technology in Biomedicine, 6*(3), 224–234.

Riva, G., Bacchetta, M., Cesa, G., Conti, S., & Molinari, E. (2003). Six-month follow-up of in-patient Experiential-Cognitive Therapy for binge eating disorders. *CyberPsychology & Behavior, 6*(3), 251–258.

Riva, G., Bacchetta, M., Cesa, G., et al. (2001). Virtual reality and telemedicine based experiential cognitive therapy: Rationale and clinical protocol. In G. Riva & C. Galimberti (Eds.), *Towards cyberpsychology: Mind, cognition and society in the Internet age* (pp. 273–308). Amsterdam: Ios Press.

Riva, G., Davide, F., & Ijsselsteijn, W. A. (Eds.). (2003). *Being there: Concepts, effects and measurements of user presence in synthetic environment*. Amsterdam: Ios Press.

Riva, G., Gaggioli, A., Grassi, A., et al. (2011). NeuroVR 2—A free virtual reality platform for the assessment and treatment in behavioral health care. *Studies in Health Technology and Informatics, 163*, 493–495.

Riva, G., Mantovani, F., Capideville, C. S., et al. (2007). Affective interactions using virtual reality: The link between presence and emotions. *Cyberpsychology & Behavior, 10*(1), 45–56.

Riva, G., & Melis, L. (1997). Virtual reality for the treatment of body image disturbances. In G. Riva (Ed.), *Virtual reality in neuro-psycho-physiology: Cognitive, clinical and methodological issues in assessment and rehabilitation* (pp. 95–111). Amsterdam: Ios Press.

Riva, G., Rizzo, A., Alpini, D., et al. (1999). Virtual environments in the diagnosis, prevention, and intervention of age-related diseases: A review of VR scenarios proposed in the EC VETERAN project. *Cyberpsychology & Behavior, 2*(6), 577–591.

Riva, G., Waterworth, J. A., & Waterworth, E. L. (2004). The layers of presence: A bio-cultural approach to understanding presence in natural and mediated environments. *Cyberpsychology & Behavior, 7*(4), 405–419.

Riva, G., & Wiederhold, B. K. (2002). Introduction to the special issue on virtual reality environments in behavioral sciences. *IEEE Transactions on Information Technology in Biomedicine, 6*(3), 193–197.

Rizzo, A. (2010). Virtual Iraq/Afghanistan and how it is helping some troops and vets with PTSD. *Veterans Today*. Retrieved from http://www.veteranstoday.com/2010/07/29/virtual-iraqafghanistan-and-how-it-is-helping-some-troops-and-vets-with-ptsd/

Rizzo, A. A., & Buckwalter, J. G. (1997). Virtual reality and cognitive assessment and rehabilitation: The state of the art. In G. Riva (Ed.), *Virtual reality in neuro-psycho-physiology* (pp. 123–146). Amsterdam: IOS Press. Retrieved from http://www.cybertherapy.info/pages/book1.htm.

Rizzo, A., Difede, J., Rothbaum, B. O., & Reger, G. (2010). Virtual Iraq/Afghanistan: Development and early evaluation of a virtual reality exposure therapy system for combat-related PTSD. *Annals of the New York Academy of Sciences (NYAS), 1208*, 114–125.

Rizzo, A. A., Klimchuk, D., Mitura, R., Bowerly, T., Buckwalter, J. G., & Parsons, T. (2006). A virtual reality scenario for all seasons: The virtual classroom. *CNS Spectrums, 11*, 35–44.

Rizzo, A. A., Neumann, U., Enciso, R., Fidaleo, D., & Noh, J. Y. (2001). Performance-driven facial animation: Basic research on human judgments of emotional state in facial avatars. *Cyberpsychology & Behavior, 4*(4), 471–487.

Rizzo, A., Parsons, T. D., Lange, B., et al. (2011). Virtual reality goes to war: A brief review of the future of military behavioral healthcare. *Journal of Clinical Psychology in Medical Settings, 18*, 176–187.

Rizzo, A., Schultheis, M. T., Kerns, K., & Mateer, C. (2004). Analysis of assets for virtual reality applications in Neuropsychology. *Neuropsychological Rehabilitation, 14*, 207–239.

Rizzo, A. A., Wiederhold, B., Riva, G., & Van Der Zaag, C. (1998). A bibliography of articles relevant to the application of virtual reality in the mental health field. *Cyberpsychology & Behavior, 1*(4), 411–425.

Rose, F. D., Brooks, B. M., & Rizzo, A. A. (2005). Virtual reality in brain damage rehabilitation: Review. *Cyberpsychology & Behavior, 8*, 241–262.

Rothbaum, B. O., Hodges, L., Alarcon, R., et al. (1999). Virtual reality exposure therapy for PTSD Vietnam Veterans: A case study. *Journal of Traumatic Stress, 12*, 263–271.

Rothbaum, B. O., Hodges, L. F., Kooper, R., Opdyke, D., Williford, J. S., & North, M. (1995). Effectiveness of computer-generated (virtual reality) graded exposure in the treatment of acrophobia. *The American Journal of Psychiatry, 152*(4), 626–628.

Rothbaum, B. O., Hodges, L., Ready, D., Graap, K., & Alarcon, R. (2001). Virtual reality exposure therapy for Vietnam veterans with post-traumatic stress disorder. *Journal of Clinical Psychiatry, 62*, 617–622.

Rothbaum, B. O., Hodges, L., Smith, S., Lee, J. H., & Price, L. (2000). A controlled study of virtual reality exposure therapy for the fear of flying. *Journal of Consulting & Clinical Psychology, 68*(6), 1020–1026.

Rothbaum, B. O., Hodges, L., & Smith, S. (1999). Virtual reality exposure therapy abbreviated treatment manual: Fear of flying application. *Cognitive & Behavioral Practice, 6*, 234–244.

Rubino, F., Soler, L., Marescaux, J., & Maisonneuve, H. (2002). Advances in virtual reality are wide ranging. *British Medical Journal, 324*(7337), 612.

Saposnik, G., Mamdani, M., Bayley, M., Thorpe, K. E., Hall, J., Cohen, L. G., et al. (2010). Effectiveness of Virtual Reality Exercises in Stroke Rehabilitation (EVREST): Rationale, design, and protocol of a pilot randomized clinical trial assessing the Wii gaming system. *International Journal of Stroke, 5*, 47–51.

Sastry, L., & Boyd, D. R. S. (1998). Virtual environments for engineering applications. *Virtual Reality: Research, Development and Applications, 3*(4), 235–244.

Satava, R. M., & Ellis, S. R. (1994). Human interface technology. An essential tool for the modern surgeon. *Surgical Endoscopy, 8*(7), 817–820.

Satava, R. M., & Jones, S. B. (2002). Medical applications of virtual reality. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 368–391). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Schneider, S. M., Kisby, C. K., & Flint, E. P. (2010). Effect of virtual reality on time perception in patients receiving chemotherapy. *Supportive Care in Cancer, 19*, 555–564. Retrieved from http://www.springerlink.com/content/?k=(au%3a(Susan?Schneider)?OR?ed%3a(Susan?Schneider))?pub%3a(Supportive?Cancer?Care).

Schultheis, M. T., & Rizzo, A. A. (2001). The application of virtual reality technology in rehabilitation. *Rehabilitation Psychology, 46*(3), 296–311.

Sharar, S. R., Carrougher, G. J., Nakamura, D., et al. (2007). Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: Preliminary results from 3 ongoing studies. *Archives of Physical Medicine and Rehabilitation, 88*(12 Suppl 2), S43–S49.

Sharar, S. R., Miller, W., Teeley, A., et al. (2008). Applications of virtual reality for pain management in burn-injured patients. *Expert Review of Neurotherapeutics, 8*(11), 1667–1674.

Skiba, D. (2009). Emerging technologies center nursing education 2.0: A second look at Second Life. *Nursing Education Perspectives, 30*(2), 129–131.

Slater, M., Perez-Marcos, D., Ehrsson, H. H., & Sanchez-Vives, M. V. (2009). Inducing illusory ownership of a virtual body. *Frontiers in Neuroscience, 3*(2), 214–220.

Stanton, D., Foreman, N., & Wilson, P. (1998). Uses of virtual reality in clinical training: Developing the spatial skills of children with mobility impairments. In G. Riva, B. Wiederhold, & E. Molinari (Eds.), *Virtual reality in clinical psychology and neuroscience* (pp. 219–232). Amsterdam: Ios Press.

Stefanidis, D., Korndorffer, J. R., Sierra, R., Touchard, C., Dunne, J. B., & Scott, D. J. (2005). Skill retention following proficiency-based laparoscopic simulator training. *Surgery, 138*, 165–170.

Strickland, D. (1997). Virtual reality for the treatment of autism. *Studies in Health Technology and Informatics, 44*, 81–86.

Székely, G., & Satava, R. M. (1999). Virtual reality in medicine. *British Medical Journal, 319* (7220), 1305.

Toth-Cohen, S., & Gallagher, T. (2009). Development and evaluation of health and wellness exhibits at the Jefferson Occupational Therapy Education Center in Second Life. *Journal of Virtual Worlds Research, 2*(2), 1–13. Retrieved 2009-08-03, from https://journals.tdl.org/jvwr/article/view/708/502.

Ustinova, K. I., Leonard, W. A., Cassavaugh, N. D., & Ingersoll, C. D. (2011). Development of a 3D immersive videogame to improve arm-postural coordination in patients with TBI. *Journal of NeuroEngineering and Rehabilitation, 8*, 61.

Verdaasdonk, E. G., Dankelman, J., Lange, J. F., & Stassen, L. P. (2008). Transfer validity of laparoscopic knot-tying training on a VR simulator to a realistic environment: A randomized controlled trial. *Surgical Endoscopy, 22*, 1636–1642.

Vincelli, F., Anolli, L., Bouchard, S., Wiederhold, B. K., Zurloni, V., & Riva, G. (2003). Experiential Cognitive therapy in the treatment of panic disorders with Agoraphobia: A controlled study. *CyberPsychology & Behavior, 6*(3), 312–318.

Vincelli, F., Choi, Y. H., Molinari, E., et al. (2001). A VR-based multicomponent treatment for panic disorders with agoraphobia. *Studies in Health Technology and Informatics, 81*, 544–550.

Vincelli, F., & Molinari, E. (1998). Virtual reality and imaginative techniques in clinical psychology. In G. Riva, B. K. Wiederhold, & E. Molinari (Eds.), *Virtual environments in clinical psychology and neuroscience*. Amsterdam: Ios Press.

Vincelli, F., Molinari, E., & Riva, G. (2001). Virtual reality as clinical tool: Immersion and three-dimensionality in the relationship between patient and therapist. *Studies in Health Technology and Informatics, 81*, 551–553.

Wang, M., & Reid, D. (2010). Virtual reality in pediatric neurorehabilitation: Attention deficit hyperactivity disorder, autism and cerebral palsy. *Neuroepidemiology, 36*, 2–18.

Whalen, E. T., Petriu, D., Yang, L., Petriu, E., & Cordea, M. D. (2003). Capturing behaviour for the use of avatars in virtual environments. *Cyberpsychology & Behavior, 6*(5), 537–544.

Whalley, L. J. (1995). Ethical issues in the application of virtual reality to medicine. *Computers in Biology and Medicine, 25*(2), 107–114.

Wiederhold, B. K., Gevirtz, R. G., & Wiederhold, M. D. (1998). Fear of flying: A case study using virtual reality therapy with physiological monitoring. *Cyberpsychology & Behavior, 1*(2), 97–104.

Wiederhold, B. K., Jang, D. P., Gevirtz, R. G., Kim, S. I., Kim, I. Y., & Wiederhold, M. D. (2002). The treatment of fear of flying: A controlled study of imaginal and virtual reality graded exposure therapy. *IEEE Transactions on Information Technology in Biomedicine, 6*(3), 218–223.

Wiederhold, B. K., & Wiederhold, M. D. (1998). A review of virtual reality as a psychotherapeutic tool. *Cyberpsychology & Behavior, 1*, 45–52.

Windich-Biermeier, A., Sjoberg, I., Dale, J. C., Eshelman, D., & Guzzetta, C. E. (2007). Effects of distraction on pain, fear, and distress during venous port access and venipuncture in children and adolescents with cancer. *Journal of Pediatric Oncology Nursing, 24*(1), 8–19.

Wolfe, B. E. (2002). The role of lived experience in self-and relational observation: A commentary on Horowitz. *Journal of Psychotherapy Integration, 12*, 147–153.

Wright, J. L., Hoffman, H. G., & Sweet, R. M. (2005). Virtual reality as an adjunctive pain control during transurethral microwave thermotherapy. *Urology, 66*(6), 1320.

Yang, X. L., Petriu, D. C., & Whalen, T. E. et al. (2003). *Script language for avatar animation in 3D virtual environments*. Presented at VECIMS 2003 International symposium on virtual environments, Human–Computer interfaces, and Measurement systems, Lugano, Switzerland.

Zhang, L., Abreu, B. C., Masel, B., Scheibel, R. S., Christiansen, C. H., Huddleston, N., et al. (2001). Virtual reality in the assessment of selected cognitive function after brain injury. *American Journal of Physical Medicine & Rehabilitation, 80*(8), 597–604.